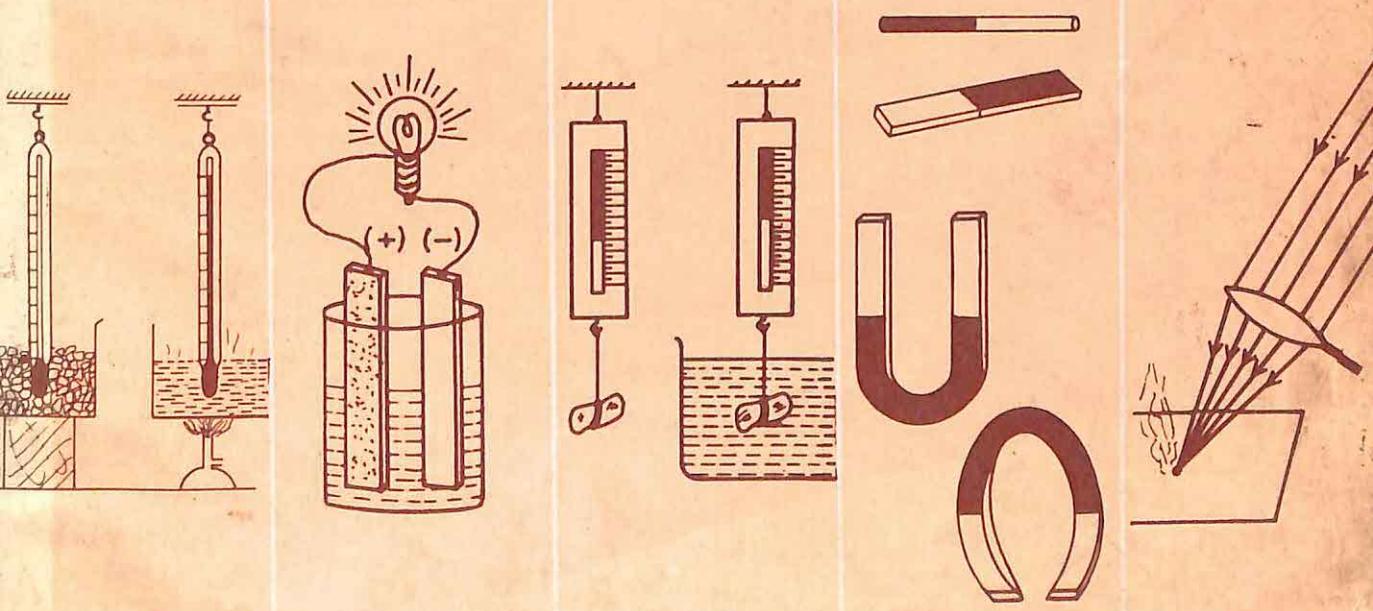


**Tata McGraw-Hill's**

# **Physics**

## **FOR CLASS VIII**

**N K Bajaj**



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**Physics**  
For Class VIII

*Based on the syllabus prescribed by the National Council of  
Educational Research & Training, New Delhi*

**N.K. BAJAJ**  
St Stephen's College  
University of Delhi



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# Preface

This book is the last in a series of three books on Physics developed for students in classes VI, VII and VIII. These books are based on the middle school syllabus prescribed by the National Council of Educational Research and Training (NCERT). The main aim in these books is to present physics in an interesting, understandable and enjoyable manner to young readers about to enter into the fascinating world of physics. Hence, the language has been kept very simple.

The author has deliberately departed from the traditional coverage of topics in classes VI, VII and VIII. The material (to be dealt with in each class) has been carefully reorganised keeping in mind the level of difficulty of the topics and the power of comprehension of the students in the relevant age-group. This has been done after detailed discussions with a wide cross-section of middle school teachers representing all shades of opinion.

This book is intended for use in Class VIII. A list of topics already covered in classes VI and VII is appended for ready reference. The author has also departed from the conventional approach in which the general principles and laws are stated first and results and inferences deduced therefrom. This approach is not in keeping with how physics is actually practised. A physical concept is first introduced by making common observations of daily experience and citing concrete examples. The relevant law or hypothesis is then suggested to explain it.

The new education policy lays considerable emphasis on pupil-oriented rather than teacher-oriented books. According to this policy, books must be designed in such a way that a pupil can read and understand on his own without undue reliance on formal classroom instruction. The pupil must play an active role in the learning process and the teacher a passive one, serving only as a guide. To understand and enjoy physics, the student must learn from his or her own experiences and not from those of others. To encourage this kind of direct encounter with reality, home experiments (or activities) have been recommended in the main body of the text in each chapter. Most of them can be performed using inexpensive materials easily available in an average household. Teachers are requested to encourage and help students do these experiments, some of which may also serve as demonstration experiments in the classroom.

The questions and exercises at the end of each chapter have been designed in accordance with the new examination techniques which are heavily biased in favour of objective testing. Questions are framed to test comprehension and application rather than the ability of a pupil to memorize facts.

To all the school teachers who have given me their valuable advice and guidance, I express my deep gratitude. It is earnestly hoped that these books will help young readers understand, enjoy and appreciate the fascinating subject of physics by making the learning process enjoyable and stimulating. In this endeavour the author would gratefully welcome suggestions for improvement of this book.

# To The Student

How does the world work? This king-sized question has a million answers. You will begin to uncover these answers—and ask several questions of your own—as you travel through the pages of this book. And as you read and understand, you will discover that the world of science is an exciting place to be in.

The journey through this book is fun-filled. It is thrilling to do experiments and try your hand at various activities—either by yourself or with your classfellows. It's like making a new discovery!

At the end of this school year, you will have a clear and comprehensive understanding of the ideas and concepts introduced in Class VI and gradually developed through classes VII and VIII.

So—go ahead. Read. Experiment. And never be afraid to ask questions.

N K BAJAJ

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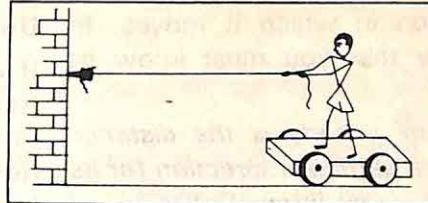
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## PHYSICS for Class VII

### CONTENTS

Motion and Speed   Energy   Density and Buoyancy   More about Heat  
Some Facts about Light   More Facts about Light   Vibrations and Sound  
The Universe



# More about Motion

## Distance and Displacement

When an object is moving from one place to another, we say it is in motion. If it stops moving, we say it is at rest. In order to describe the motion of an object it is necessary to know the *distance* the object travels in a certain time.

Let us suppose that a man travels from Delhi to Bombay—a distance of 1,500 km. Another man also wishes to travel from Delhi to Bombay. Will he reach Bombay if he travels a distance of 1,500 km in any direction? The obvious answer is, no. He must know the direction in which he must travel that distance. In physics we say that he must know the *displacement*. *Displacement is the distance travelled by a body in a particular direction.*

## Speed and Velocity

In order to describe the motion of an object, it is necessary to know not only the distance the body travels but also the time it takes to travel that distance. Distance and time are related to each other by the term *speed*. You already know what is meant by speed of a moving object. *The speed of an object is the distance which the object travels in a unit interval of time.* It is expressed in *metres per*

*second (m/s).*

While describing motion, not only the speed but also the direction in which the object moves is important. Suppose two towns B and C are situated at a distance of 60 km from town A. Town B is to the east of town A and town C is to the north of town A (see Fig. 1.1). Suppose a car starts from town A

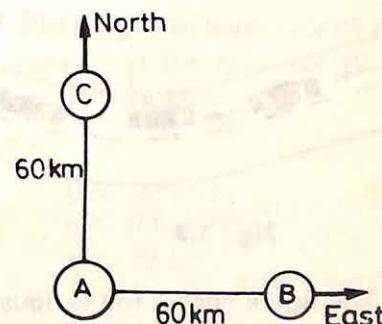


Fig. 1.1

at a speed of 60 km/h. After one hour it will reach town B only if it moves in the direction of the east. If the car has to go to town C in one hour, it must travel in the direction of the north. If it travels in any other direction, it will be at some other place after one hour. Thus, to know where the car would be after one hour, you must know not only its speed but

also the direction in which it moves. In physics, we say that you must know its *velocity*.

*The velocity of a body is the distance travelled by it in a particular direction (or its displacement) in a unit interval of time.*

Suppose two cars start from town A at the same speed of 60 km/h. The first car travels towards town B and the second towards town C. The speed of the two cars is the same but they have different velocities because they are travelling in different directions. Thus the *velocity of a moving body is its speed in a particular direction. If two bodies have the same speed and are moving in the same direction, they have the same velocity.* Velocity is also measured in *metres per second (m/s).*

#### Constant Speed is not the Same as Constant Velocity

Figure 1.2 shows a car moving along a cur-

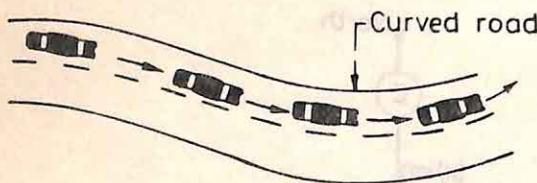


Fig. 1.2

ved road. The figure shows the various positions of the car on the road. At each position an arrow is drawn to show the direction in which the car is moving at that instant of time. Let us assume that the car is moving at a constant speed of 60 km/h. As the car takes a bend, its velocity changes in spite of the fact that its speed remains constant at 60 km/h. The velocity changes because the direction changes as the car goes on a curve. *An object has a constant velocity if its speed as well as its direction do not change with time.*

#### Uniform and Variable Velocity

If a body moving *in a particular direction* travels equal distances in equal intervals of time, however short the time interval may be, its velocity is said to be *constant* or *uniform*. In other words, a body has a *uniform velocity* if its speed and its direction do not change with time. If either its speed or its direction or both change with time, the velocity of the body is said to be *variable*.

#### Acceleration

Suppose a car is moving with a certain velocity. The driver presses his foot on the accelerator and the car begins to move faster. We say that the car is *accelerating*, that is, its velocity is increasing with time. Suppose a car starts from rest and speeds up to 60 km/h in a certain time—it is accelerating during this time. If a second car also starts from rest and speeds up to 60 km/h in less time than the first car, it has a greater acceleration than the first.

*Acceleration is defined as the rate of change of velocity.* In other words, *acceleration is the change in velocity per unit time.* Or,

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time}}$$

#### Unit of Acceleration

Like velocity, acceleration is a rate. Velocity is the rate at which the displacement of an object changes. Acceleration is the rate at which the velocity of the object changes. Thus acceleration is the 'rate of a rate'. Let us consider an example.

Suppose a car is moving with a velocity of 10 m/s. The driver presses his foot on the accelerator and in 5 seconds the velocity of the car becomes 20 m/s. The change in its velocity is simply the final velocity minus the initial velocity, that is, change in velocity = 20 m/s

–  $10 \text{ m/s} = 10 \text{ m/s}$  or 10 metres per second. This change has been brought about in 5 seconds. Therefore, the acceleration of the car is

$$\frac{10 \text{ metres per second}}{5 \text{ seconds}}$$

$$= 2 \text{ metres per second per second}$$

2 metres per second per second is written as  $2 \text{ m/s}^2$  which is read as 2 metres per second squared.

In the MKS system, the unit of acceleration is *metres per second per second* (symbol  $\text{m/s}^2$ ). Notice that there are two 'pers' in the time unit. This is because acceleration is 'the rate of a rate'. An acceleration of  $2 \text{ m/s}^2$  means that the velocity of the body increases by 2 metres per second in every second.

Suppose a car is moving with a velocity of  $10 \text{ m/s}$ . The driver presses his foot on the accelerator and the acceleration produced in the car is  $5 \text{ m/s}^2$ . What is the velocity of the car after 4 seconds? Let us find out. The acceleration of the car is  $5 \text{ m/s}^2$ . This means that the velocity of the car increases by  $5 \text{ m/s}$  in every second. Therefore, the velocity of the car after 1s, 2s, 3s, etc., is as follows:

At the start, the velocity of the car =

$$10 \text{ m/s}$$

After 1s, the velocity of the car =  $10 + 5 = 15 \text{ m/s}$

After 2s, the velocity of the car =  $10 + 5 + 5 = 10 + (5 \times 2) = 20 \text{ m/s}$

After 3s, the velocity of the car =  $10 + 5 + 5 + 5 = 10 + (5 \times 3) = 25 \text{ m/s}$

After 4s, the velocity of the car =  $10 + (5 \times 4) = 30 \text{ m/s}$  and so on (see Fig. 1.3).

Therefore,

After  $t$  seconds, the velocity of the car =  $10 + (5 \times t) \text{ m/s}$ .

Suppose the car started with a velocity  $u$  m/s and has an acceleration of  $a$  m/s $^2$ . After  $t$  seconds, let the velocity of the car be  $v$  m/s. Then the above example shows that

$$v = u + at$$

where  $u$  = initial velocity of the car

$a$  = acceleration of the car

and  $v$  = final velocity after  $t$  seconds.

The above formula is a relation between four quantities:  $u$ ,  $v$ ,  $a$  and  $t$ . If any three quantities are known, the fourth can be calculated using this formula. Look at the following examples.

### EXAMPLE 1

A car is moving with a velocity of  $20 \text{ m/s}$ . It is accelerated at  $0.5 \text{ m/s}^2$  for 10 seconds. Calculate its final velocity.

*Solution*

$$u = 20 \text{ m/s}$$

$$a = 0.5 \text{ m/s}^2$$

$$t = 10 \text{ s}$$

$$v = ?$$

$$\text{Now } v = u + at$$

$$\text{Hence } v = 20 + 0.5 \times 10$$

$$= 20 + 5 = 25 \text{ m/s}$$

### EXAMPLE 2

A body, starting from rest, accelerates for 5

Time (s)	0	1	2	3	4
Velocity (m/s)	10	15	20	25	30

Fig. 1.3

seconds and acquires a velocity of 10 m/s. Calculate the value of the acceleration.

**Solution**

$$u = 0 \text{ (}\because \text{ the object starts from rest)}$$

$$t = 5 \text{ s}$$

$$v = 10 \text{ m/s}$$

$$a = ?$$

Substituting these values in the formula,  $v = u + at$ , We have

$$10 = 0 + a \times 5$$

$$\text{or } 5a = 10$$

$$\text{or } a = 2 \text{ m/s}^2$$

You may also find the acceleration  $a$  by using the definition

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time}}$$

$$= \frac{\text{final velocity} - \text{initial velocity}}{\text{time}}$$

$$\text{or } a = \frac{v - u}{t}$$

$$= \frac{10 \text{ m/s} - 0}{5 \text{ s}} = \frac{10 \text{ m/s}}{5 \text{ s}} = 2 \text{ m/s}^2$$

### EXAMPLE 3

A car moving with a velocity of 15 m/s accelerates to 30 m/s at a rate of 3 m/s<sup>2</sup>. In how much time did it reach its final velocity?

**Solution**

$$u = 15 \text{ m/s}$$

$$v = 30 \text{ m/s}$$

$$a = 3 \text{ m/s}^2$$

$$t = ?$$

Using the formula  $v = u + at$ , we have

$$30 = 15 + 3t$$

$$\text{or } 3t = 30 - 15 = 15$$

$$\text{or } t = 5 \text{ seconds}$$

### EXAMPLE 4

A car reached a velocity of 30 m/s after ac-

celerating at the rate of 2 m/s<sup>2</sup> for 6 seconds. What was its initial velocity?

**Solution**

$$v = 30 \text{ m/s}$$

$$a = 2 \text{ m/s}^2$$

$$t = 6 \text{ s}$$

$$u = ?$$

Now

$$v = u + at$$

$$u = v - at$$

$$= 30 - 2 \times 6$$

$$= 30 - 12 = 18 \text{ m/s}$$

### Free Fall : Acceleration due to Gravity

If you hold an object such as a ball or a stone above the ground and let it go, it falls downwards. It falls because of the gravity of the earth. The gravitational force of the earth pulls the object downwards.

It is commonly thought that heavier objects fall faster than lighter objects. Take a heavy object like a stone in one hand and in your other hand take a lighter object like a piece of paper. Hold them at the same height above the ground and let them go at the same time. The stone reaches the ground earlier than the paper.

It was Galileo Galilei (1564-1642) of Italy who performed many experiments dropping objects of various sizes and masses from the Leaning Tower of Pisa and came to the conclusion that, *if air were absent, all bodies would fall at the same rate*. It is the friction (or resistance) of air that slows down the piece of paper. In the absence of air, it would have dropped just as fast as the stone.

Galileo's conclusion was proved by Sir Isaac Newton (1642-1727) by his famous Guinea and Feather experiment shown in Fig. 1.4. He took a long glass tube and inserted in it a guinea (a coin) and a feather. When the tube was inverted the coin travelled much faster than the feather (Fig. 1.4 a). Then with

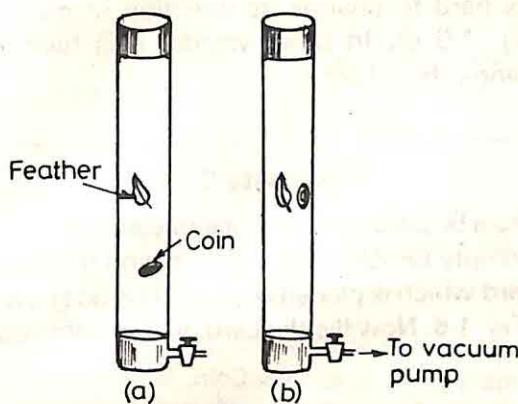


Fig. 1.4

the help of a vacuum pump, the air from the tube was removed. The experiment was repeated with the evacuated tube. Both the coin and the feather were seen to travel together and hit the other end of the tube at the same time (Fig. 1.4 b). Thus we conclude that, *in the absence of air, all bodies fall at the same rate*.

Galileo went a step further and said that during a free fall, the velocity of the falling body does not remain constant, it keeps on increasing. You can easily see it for yourself.

### Activity 1

Take a brick and a long nail. Fix the nail on the ground. Drop the brick on the head of the nail from a height of one metre. The nail is driven into the ground. Repeat the experiment by dropping the same brick from a height of half-a-metre or less. You will find that the nail is driven much farther into the ground in the first case than in the second case. Clearly the brick must be *moving faster in the first case than in the second*.

Experiments have shown that the velocity of a body falling freely under gravity increases

at a constant rate. *In the absence of air, all bodies fall with the same constant acceleration*. In most practical situations, the presence of air has a negligible effect. Only in the special case of a very light object with a large area such as a piece of paper, a feather, or a parachute, does air slow down falling bodies. Except in these exceptional cases, objects fall with the same acceleration. This acceleration is known as *acceleration due to gravity* and is usually denoted by the symbol  $g$ . The value of  $g$  has been found experimentally.

$$g = 9.8 \text{ m/s}^2$$

### EXAMPLE 5

A stone is dropped (from rest) from the top of a building and reaches the ground in 3 seconds. With what velocity does the stone hit the ground?

#### Solution

$$u = 0 \text{ (} \because \text{ the stone is dropped from rest)}$$

$$t = 3 \text{ s}$$

$$g = 9.8 \text{ m/s}^2$$

$$v = ?$$

The formula  $v = u + at$  becomes  $v = u + gt$  in this case.

$$\text{Hence } v = 0 + 9.8 \times 3$$

$$\text{or } v = 29.4 \text{ m/s}$$

### Motion and Inertia

Roll a marble on a rough floor. The marble travels a certain distance and gradually comes to rest. You have learnt earlier that a force can stop a moving object. Which force is now acting on the marble? It is the force of friction between the marble and the floor which slows it down. Now roll the marble on a smooth polished floor with the same force as before. It travels a much longer distance before coming to rest. The reason is that a

smooth surface offers much less friction than a rough surface.

If we imagine that friction is completely absent then we should expect the marble to keep moving with the same speed and in the same direction for all time to come. This is because there would be no force acting on the marble. Thus we find that *unless a force is applied, a stationary body will stay at rest and a moving body will continue to move in a straight line with the same speed. In other words, the state of rest or of uniform motion in a straight line of a body can be changed only if a force acts on the body.*

All objects, stationary or moving, resist any attempt to change their state of rest or motion. This property of a body is called *inertia*.

*Inertia is the property or tendency of a body to resist any change in its state of rest or of uniform motion in a straight line.*

The name inertia was given by Galileo. A body is said to have large inertia if it is hard to move when it is at rest or to change its speed or direction of motion when it is moving. Thus, a heavy truck or heavy stone has large inertia and a pencil or safety pin has very little inertia. *Mass is a measure of inertia of a body.* The heavier the body, the larger its inertia.

Figure 1.5 illustrates the concept of inertia. If a body has large inertia, it is hard to make it move as shown in Fig. 1.5a. If a body with large inertia is moving, it is hard to stop it or change its speed (Fig. 1.5 b). Similarly,

it is hard to change its direction of motion (Fig. 1.5 c). In other words, it is hard to change its velocity.

### Activity 2

Take a 50 paise coin, a piece of cardboard and an empty tumbler. Place the coin on the cardboard which is placed on a tumbler as shown in Fig. 1.6. Now flip the card quickly with your

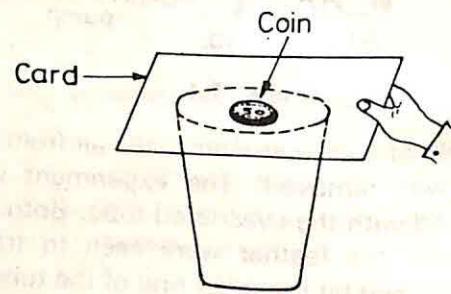


Fig. 1.6

finger. The coin will neatly drop into the tumbler. Does this observation show that the coin has inertia and it resists any attempt to change its state of rest?

A railway wagon detached from a moving train can travel a few kilometres before coming to rest. It would never stop if the friction between its wheels and the railway track and the friction offered by air were absent.

You have the first-hand experience of the inertia of your body when you travel in a bus. What happens when a stationary bus sudden-

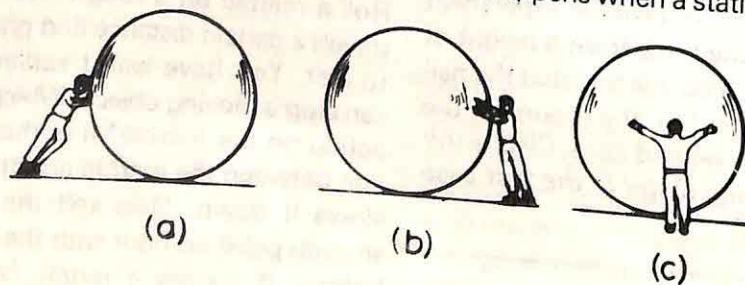


Fig. 1.5

ly starts moving? You are thrown backwards because your body is at rest and tends to stay at rest even after the bus has started. On the other hand, when a moving bus suddenly stops, you are thrown forward and your head may hit the front seat. The reason is that your body is in motion with the bus and tends to stay in motion even after the bus has stopped.

### Force and Acceleration

When a force acts on a body it changes its state of rest (if it is stationary) or its state of uniform motion (if it is moving). In other words, a force changes the velocity of a body. If the velocity of a body changes, it is accelerated. Thus *a force produces an acceleration in a body*.

The acceleration produced in a body by a force depends upon (i) the magnitude of the force applied and (ii) the mass of the body. Try the following experiment and find out for yourself.

### Activity 3

Take a carromboard. Place a carrom coin about 5 cm from the striker. Push the striker so that it hits the coin. The coin moves due to impact. Next, hit the coin harder than before. The coin moves faster than before; it has a greater acceleration. This shows that if the force is increased, it produces greater acceleration in the body.

Now, with the help of some plasticine, join two carrom coins together. You have now got a composite coin of mass equal to twice the mass of a single coin. Hit this composite coin with the striker with the same force. The composite coin does not move as fast as a single coin does. You need a little practice to exert nearly the same force in the two cases. This shows that *the greater the mass, the smaller the acceleration produced by a force*.

Thus we find that when a force acts on a body

- it produces an acceleration in the body
- the acceleration produced is greater if the force is increased and smaller if the force is decreased
- the acceleration produced is greater in a lighter body than in a heavier body if the same force acts on both

### Unit of Force

We are now in a position to define a unit of force. In the MKS system, the unit of force is the *newton*. It is defined as follows: *One newton is the force, which, when applied to a mass of 1 kg, produces an acceleration of 1 m/s<sup>2</sup>*. The symbol for *newton* is N. Thus 5 N force when applied to mass of 1 kg will produce an acceleration of 5 m/s<sup>2</sup>. Similarly *9.8 N force will produce an acceleration of 9.8 m/s<sup>2</sup> in a mass of 1 kg*.

Since 9.8 m/s<sup>2</sup> is the acceleration due to gravity, 9.8 N is the force with which a body of mass 1 kg is pulled by the gravity of the earth. This force is, therefore, called a kg wt. We now know that

$$1 \text{ kg wt} = 9.8 \text{ N}$$

Thus 1 kg wt is the force which produces an acceleration of 9.8 m/s<sup>2</sup> in a body of mass 1 kg.

A force of 4 N produces an acceleration of 4 m/s<sup>2</sup> in a body of mass 1 kg, or an acceleration of 1 m/s<sup>2</sup> in a body of mass 4 kg, or an acceleration of 2 m/s<sup>2</sup> in a mass of 2 kg.

These examples give us a relation between force, mass and acceleration. *If a force F newtons acts on a body to mass m kg and produces an acceleration a m/s<sup>2</sup>, then*

$$F = m \times a$$

*or Force = mass × acceleration*

This is the relation between three quantities *F, m and a*. If any two quantities are known,

the third quantity can be calculated using this relation. Remember that force  $F$  is in newtons, mass  $m$  in kilograms and acceleration  $a$  in metres per second squared. Look at the following examples.

#### EXAMPLE 6

Calculate the force which will produce an acceleration of  $3.5 \text{ m/s}^2$  in a body of mass 4 kg.

*Solution*

$$a = 3.5 \text{ m/s}^2$$

$$m = 4 \text{ kg}$$

$$F = m \times a = 4 \text{ kg} \times 3.5 \text{ m/s}^2 \\ = 14 \text{ N}$$

#### EXAMPLE 7

A force of 10 N acts on a body of mass 200 g. Calculate the acceleration produced.

*Solution*

$$F = 10 \text{ N}$$

$$m = 200 \text{ g} = \frac{200}{1000} \text{ kg} = 0.2 \text{ kg}$$

Now

$$F = m \times a$$

$$\therefore a = \frac{F}{m} = \frac{10 \text{ N}}{0.2 \text{ kg}} = 50 \text{ m/s}^2$$

#### EXAMPLE 8

A force of 1500 N produces an acceleration of  $6 \text{ m/s}^2$  in a car. Find the mass of the car.

*Solution*

$$F = 1500 \text{ N}$$

$$a = 6 \text{ m/s}^2$$

Now  $F = m \times a$

$$\therefore m = \frac{F}{a} = \frac{1500 \text{ N}}{6 \text{ m/s}^2} = 250 \text{ kg}$$

#### EXAMPLE 9

A body has a mass of 10 kg. What is the force

of gravity acting on it. Express your answer in kg wt and newtons.

*Solution*

The force of gravity is 10 kg wt. Now

$$1 \text{ kg wt} = 9.8 \text{ N}$$

$$\therefore 10 \text{ kg wt} = 10 \times 9.8 \text{ N} = 98 \text{ N}$$

#### Action and Reaction

Figure 1.7 shows a boy standing on a trolley and holding one end of a rope. The other end

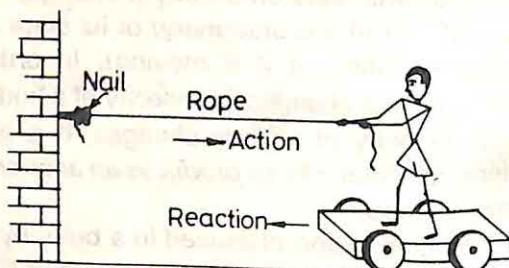


Fig. 1.7

of the rope is tied to a nail fixed firmly in a wall. The boy pulls on the rope. What happens? The trolley moves towards the wall. You know that only a force can move a body at rest. Which force is moving the trolley? The boy is not exerting a force on it. He is exerting a force on the wall. This force is called the *action*. How does the trolley move? Who is exerting a force on it? It is the wall which exerts a force on the trolley. This force is called the *reaction*. Thus, forces always occur in pairs. Newton called the pairs *action* and *reaction*.

*The forces of action and reaction are in opposite directions.* Notice that the forces of action and reaction do not act on the same body; they act on different bodies. In Fig. 1.7 the action force acts on the wall and the wall, in turn, exerts a reaction force on the trolley.

#### More Examples of Action and Reaction

1. Sit on a chair placed near a heavy table.

Try to pull the table towards yourself. What happens? Your chair moves towards the table. The force you exerted on the table is the action. The table, in turn, exerts a force on you and the chair—this force is the reaction. Action and reaction act in opposite directions on different bodies. The force of action is exerted on the table and the force of reaction is exerted on the chair.

2. Try this interesting experiment yourself. Blow up a balloon and hold its mouth firmly in your hand as shown in Fig. 1.8a. Sud-

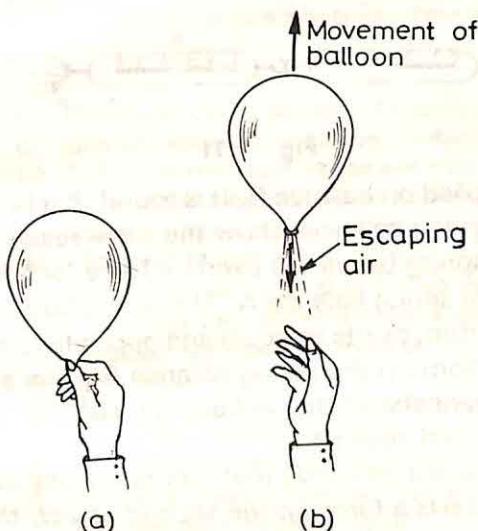


Fig. 1.8

denly release the balloon and watch its movement. The balloon will move away from your hand (Fig. 1.8b). The air escapes from the mouth with a force (action). The escaping air pushes the balloon in the opposite direction (reaction).

3. The motion of rockets depends on action and reaction. The rocket expels hot gases with a very large force (action). The escaping gases exert an opposite force on the rocket (reaction). You have played with rockets during Deepawali. When you set

fire to a rocket, the chemicals pasted in its head are ignited. The rocket expels hot gases in the downward direction and the rocket itself moves in the upward direction. This is shown in Fig. 1.9.

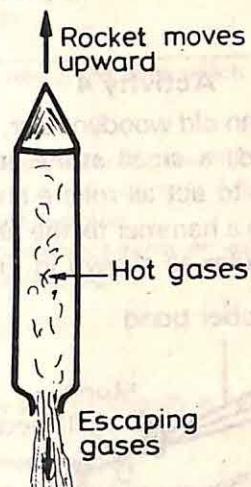


Fig. 1.9

4. A motorboat pushes water backwards and the water exerts an opposite force on the boat in the forward direction.
5. When a boatman wants to go away from the bank of a river, he pushes on the bank with his pole (action). The bank pushes the boat in the opposite direction (reaction).
6. Suppose you are standing on the ground. In order to start walking you push your foot against the ground. You exert a force on the ground (action). The ground exerts an opposite force on you (reaction). It is this force which causes you to move forward. To move a stationary object (in this case you are the object), a force must be exerted on that very object. The only force exerted on you is the one exerted by the ground.
7. When a gun is fired, the bullet moves forward with a very high speed. The forward push exerted by the gun on the bullet is

the action. The reaction is the force exerted by the bullet on the gun. This force pushes the gun backwards. The backward movement of the gun when it is fired is called its *recoil*. Try the following experiment and see this effect yourself.

#### Activity 4

You will need an old wooden ruler, three nails, a rubber band, a small stone, three small round pencils to act as rollers and a box of matches. With a hammer fix the nails firmly in the wooden ruler as shown in Fig. 1.10.

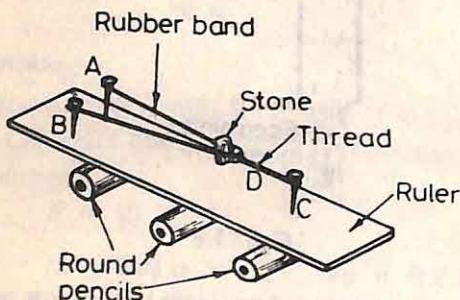


Fig. 1.10

Cut the rubber band and tie its ends to nails A and B as shown in Fig. 1.10. Tie one end of a thread to the midpoint of the rubber band. Stretch the rubber band by pulling at the thread. Tie the other end of the thread to nail C, making sure that the rubber band

is well stretched. Fix the stone between the rubber bands as shown. Now place the ruler on three round pencils.

The stone is the bullet and the ruler is your gun. Light a match and burn the thread at point D. What do you observe? The stone moves forward and the ruler recoils in the backward direction.

#### Action and Reaction are Equal and Opposite

A spring balance A is fixed to a wall. The hook of this balance is attached to another spring balance B as shown in Fig. 1.11. A pull force

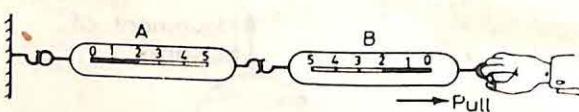


Fig. 1.11

is applied on balance B. It is found that both the spring balances show the same reading. The spring balance B exerts a force (action) on the spring balance A. The spring balance A, in turn, exerts an equal and opposite force (reaction) on the spring balance B. This experiment shows that action and reaction are equal and opposite.

Thus we conclude that *whenever one object exerts a force on the second object, the second object exerts an equal and opposite force on the first or to every action there is an equal and opposite reaction.*

#### POINTS TO REMEMBER

1. Displacement of a body is the distance it travels in a particular direction.
2. Speed of a body is the distance travelled by it in a unit interval of time. Velocity of a body is the distance travelled by it in a particular direction (i.e. its displacement) in a unit interval of time.
3. In the MKS system, speed or velocity is expressed in metres per second (m/s).
4. A body has a uniform velocity if its speed as well as its direction of motion do not change with time.
5. Acceleration is the rate of change of velocity. In the MKS system, the unit of acceleration is metres per second per second or metres per second squared (m/s<sup>2</sup>).
6.  $v = u + at$   
where  $u$  = initial velocity of the body

$a$  = acceleration of the body

and  $v$  = final velocity after  $t$  s

- All bodies fall on earth with the same constant acceleration called acceleration due to gravity ( $g$ ).  

$$g = 9.8 \text{ m/s}^2$$
- Inertia is the property or tendency of a body to resist any change in its state of rest or of uniform motion in a straight line. Mass is a measure of inertia of a body.
- Force is an agency which produce acceleration in a material body.  

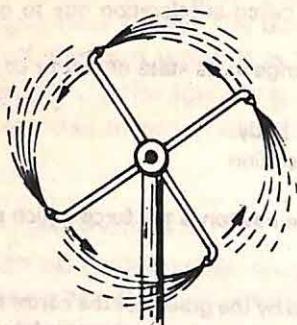
$$\text{Force} = \text{mass} \times \text{acceleration}$$
  

$$\text{or } F = m \times a$$
- In the MKS system, the unit of force is called *newton* (N). One newton is the force which produces an acceleration of  $1 \text{ m/s}^2$  in a body of mass 1 kg.  

$$1 \text{ kg wt} = 9.8 \text{ N}$$
  
 One kg wt is the force with which a body of mass 1 kg is pulled by the gravity of the earth. In other words, 1 kg wt is the force which produces an acceleration of  $9.8 \text{ m/s}^2$  in a body of mass 1 kg.
- Forces always occur in pairs. Newton called these pairs action and reaction.
- Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first or to every action there is an equal and opposite reaction.

### QUESTIONS

- (a) Distinguish clearly between the terms *speed* and *velocity*.  
 (b) Give an example of a motion in which the speed is constant but the velocity is variable.
- (a) Define the term *acceleration* and state its unit.  
 (b) A car accelerates at a rate of  $5 \text{ m/s}^2$ . What does this statement mean?
- (a) A body is moving with a uniform velocity of  $5 \text{ m/s}$ . How far will it go in one minute?  
 (b) The speed of light is  $3 \times 10^8 \text{ m/s}$ . How many minutes does it take for the light of the sun to reach us on earth which is  $1.5 \times 10^8 \text{ km}$  away?
- (a) A car starts from rest and acquires a speed of  $20 \text{ m/s}$  in 10 seconds. What is the acceleration of the car?  
 (b) An object has an initial velocity of  $10 \text{ cm/s}$  and is being accelerated at a constant rate of  $5 \text{ cm/s}^2$ . What is its velocity after 5 s?  
 (c) A car whose initial speed is  $10 \text{ m/s}$  receives an acceleration of  $2 \text{ m/s}^2$ . How long does it take the car to acquire a speed of  $20 \text{ m/s}$ ?
- (a) What is acceleration due to gravity? What is its value on earth?  
 (b) A stone is dropped (from rest) from the top of a building. It reaches the ground in 2 s. With what velocity does the stone hit the ground?
- (a) What do you understand by the term *inertia of a body*?  
 (b) Describe an experiment which shows that a body at rest tends to stay at rest.
- (a) What is meant by the term *force*?  
 (b) State and define the unit of force in the MKS system.  
 (c) A force of  $20 \text{ N}$  acts on a body of mass  $5 \text{ kg}$ . What is the acceleration produced?  
 (d) How much force will produce an acceleration of  $5 \text{ m/s}^2$  in a body of mass  $10 \text{ kg}$ ?  
 (e) A force of  $25 \text{ N}$  acts for 4 s on a body of mass  $2 \text{ kg}$  initially at rest. Determine (i) the acceleration produced and (ii) the velocity of the body at the end of 4 s.
- (a) Give two examples which show that action and reaction are opposite.  
 (b) Describe an experiment which shows that action and reaction are equal and opposite.  
 (c) Look at the pictures (a) and (b) shown in Fig. 1.12 and indicate the action and reaction involved.  
 (d) Figure 1.13 shows two boys A and B standing on skate boards holding a long rope between them. A pulls the rope towards himself. Pick the correct statements from the following:  
 (i) B moves towards A but A remains stationary.  
 (ii) A moves towards B but B remains stationary.



(a) Garden water sprinkler



(b) A boy rowing a boat with oars

Fig. 1.12

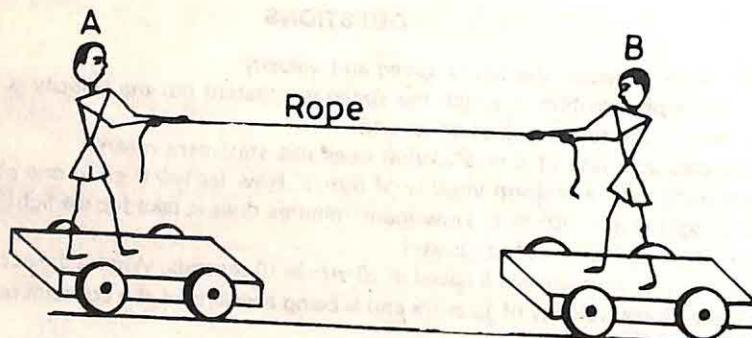


Fig. 1.13

(iii) Both A and B move towards each other.  
 (iv) B does not exert any force on A.  
 (v) A exerts a force of action on B and B exerts a force of reaction on A.  
 (vi) A exerts a force of reaction on B and B exerts a force of action on A.  
 (vii) The action and reaction both act on A.  
 (viii) The action and reaction both act on B.

9. Give reasons for the following.

(i) Passengers fall backwards when a bus suddenly starts.  
 (ii) Passengers are jerked forward when a moving bus suddenly stops.  
 (iii) A gun recoils when it is fired  
 (iv) A body weighs less on the moon than on the earth.  
 (v) Dust particles are removed from a carpet by beating it with a stick.

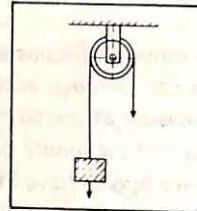
10. Mark true or false

(i) Mass and weight are both measured in kilograms.  
 (ii) A body moving at constant speed has a constant velocity.  
 (iii) A body moving with constant velocity has no acceleration.

- (iv) A body can move with constant velocity only if a force acts on it.
- (v) Only a force can produce acceleration in a material body.
- (vi) Mass is a measure of inertia of a body.
- (vii) Both moving and stationary bodies have inertia.
- (viii) Only stationary bodies have inertia.
- (ix) A bicycle has more inertia than a car if both are moving at the same speed.
- (x) Action and reaction act on different bodies.

11. Fill in the blanks using the choices given in brackets.

- (i) The MKS unit of mass is \_\_\_\_\_ and that of weight is \_\_\_\_\_ (kg, m/s<sup>2</sup>, N).
- (ii) The unit of acceleration is \_\_\_\_\_ (m/s, N, m/s<sup>2</sup>).
- (iii) Acceleration = force ÷ \_\_\_\_\_ (mass, weight, velocity).
- (iv) 1 newton is approximately equal to \_\_\_\_\_ kg wt (1/10, 1, 10)
- (v) 1 newton of force will produce in a mass of 1 kg an acceleration of \_\_\_\_\_ cm/s<sup>2</sup> (1, 10, 100).
- (vi) The acceleration of a body is 2 m/s<sup>2</sup>. This means that the velocity of the body increases by \_\_\_\_\_ m/s every 2 seconds. (1, 2, 3, 4).
- (vii) If the friction of air is neglected, all bodies will fall to the earth with the same \_\_\_\_\_ (velocity, force, acceleration).
- (viii) The force with which a body of mass 1 kg is pulled by the earth is equal to \_\_\_\_\_ N (1, 1/9.8, 9.8).
- (ix) If a force of  $x$  newtons produces an acceleration of  $y$  m/s<sup>2</sup> in a body of mass  $z$  kg then  $x =$  \_\_\_\_\_ ( $yx$ ,  $y/z$ ,  $z/y$ ).
- (x) A body moving in a circle with a constant speed has a \_\_\_\_\_ velocity (uniform, variable).



# 2

# Work and Simple Machines

Everybody does some work every day. You work when you play or pedal a bicycle or lift a load. Some people work in offices others work in factories. People in factories perform manual work like lifting and carrying heavy loads.

In general conversation we use the word *work* rather vaguely. For example, we say that Rajesh is more hardworking than Rahul or that Ram is very active and can do a lot of work. In physics, however, the word *work* has a special meaning. Let us try to understand what a scientist means by the term *work*.

## Work

### Work and Motion

In physics, work is defined in a very special way that describes what is achieved by the action of a force on a body. *Work is said to be done if the force applied to the body succeeds in moving it. If no motion takes place, no work is said to be done.* For example, a horse pulling a cart does work, an engine pulling a train does work, a person lifting a load does work, a cyclist pedalling a bicycle does work, and so on.

However, a person may exert a force and yet do no work. For example, a man pushing against a wall does no work if the wall does

not move. He may get tired but he does no work if he does not succeed in moving the wall. Similarly, if you hold a heavy object in your hand and stay motionless, you do no work even though you may get tired holding it.

Thus, for work to be done, two conditions must be fulfilled:

- (i) a force must be applied
- (ii) the force must produce motion.

### Measurement of Work

If you lift a box full of heavy articles from the ground floor to the first floor of your house, you would have to do more work than if you lift the empty box through the same distance. You would have to apply a greater force to lift the box full of articles than to lift the empty box. This shows that the *work done depends upon the magnitude of the force applied*.

Now suppose you lift the box full of articles from the ground floor to the second floor of your house. You would have to do more work than if you lift the same box from the ground floor to the first floor. This shows that the *work done depends also on the distance through which the force is applied*.

Thus we conclude that the amount of work depends on the magnitude of the applied

force as well as the distance moved in the direction of the force. The work ( $W$ ) done by a force ( $F$ ) on a body is given by the product of the force and the distance ( $D$ ) moved in the direction of the force.

$$W = F \times D$$

In the MKS system, the unit of work is called the *joule* (symbol J). *One joule of work is said to be done if a force of one newton acting on a body moves it through a distance one metre in the direction of the force.*

$$1 \text{ joule} = 1 \text{ newton} \times 1 \text{ metre}$$

$$\text{or } 1 \text{ J} = 1 \text{ N} \times 1 \text{ m} = 1 \text{ Nm}$$

*One newton metre is called one joule.*

#### EXAMPLE 1

A force of 250 N moves a body through a distance 4 m. Calculate the work done by the force.

*Solution*

$$\begin{aligned} \text{Force (F)} &= 250 \text{ N} \\ \text{Distance (D)} &= 4 \text{ m} \\ \text{Work done (W)} &= F \times D \\ &= 250 \text{ N} \times 4 \text{ m} \\ &= 1000 \text{ N m} = 1000 \text{ J} \end{aligned}$$

#### EXAMPLE 2

Calculate the work done in lifting a mass of 5 kg to a height of 50 cm. 1 kg wt = 10 N

*Solution*

An object of mass 5 kg has a weight of 5 kg wt. This is force which must be applied to lift it against gravity. Therefore

$$F = 5 \text{ kg wt} = 5 \times 10 = 50 \text{ N}$$

$$\text{Now Distance moved (D)} = 50 \text{ cm} = 0.5 \text{ m}$$

$$\begin{aligned} \text{Work done (W)} &= F \times D \\ &= 50 \text{ N} \times 0.5 \text{ m} \\ &= 25 \text{ N m} = 25 \text{ J} \end{aligned}$$

## Simple Machines

### What is a Machine?

Machines play a very important role in our lives. Machines help us to do work more easily. You must have seen people doing different kinds of jobs with the help of machines. Many jobs are so difficult that they cannot be done without the help of machines. Many other jobs, which are not so difficult, are made much easier by machines. Let us look at some examples.

Suppose you are asked to open a tight-fitting lid of a tin. What would you do? You would not be able to open the lid with your finger nails. Take a spoon and insert the handle of the spoon between the lid and the edge of the tin. Now press the other end of the spoon. The lid comes off (Fig. 2.1). Here the spoon serves as a machine to do the job of opening the lid.

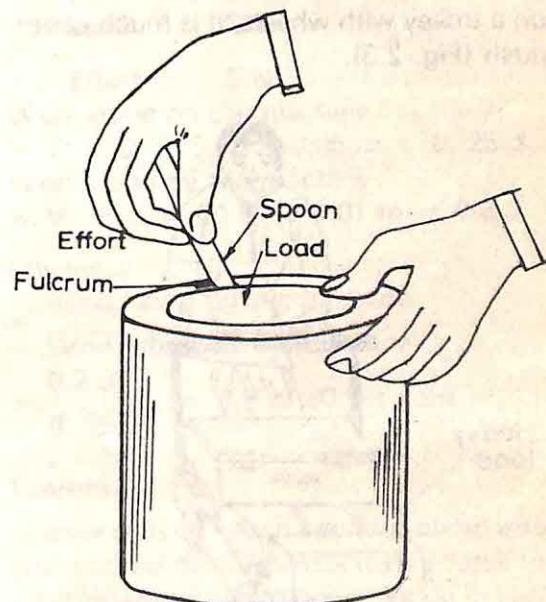


Fig. 2.1

Suppose you wish to open a corked bottle. What do you do? You take a screw, in-

sert it in the cork and pull. The bottle is easily opened (Fig. 2.2).

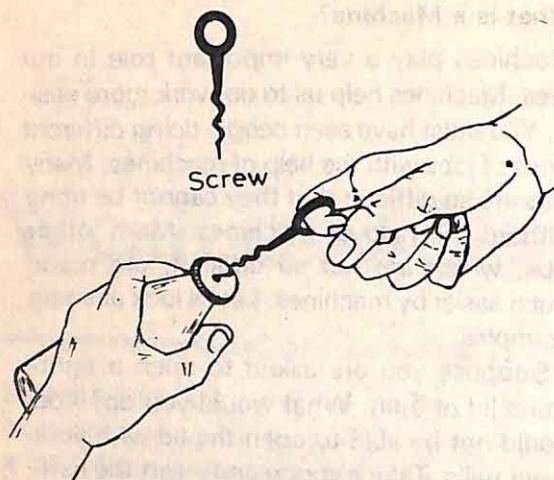


Fig. 2.2

Suppose you wish to move a very heavy load from one place to another. It is not easy to lift or push a heavy object. But if it is placed on a trolley with wheels, it is much easier to push (Fig. 2.3).

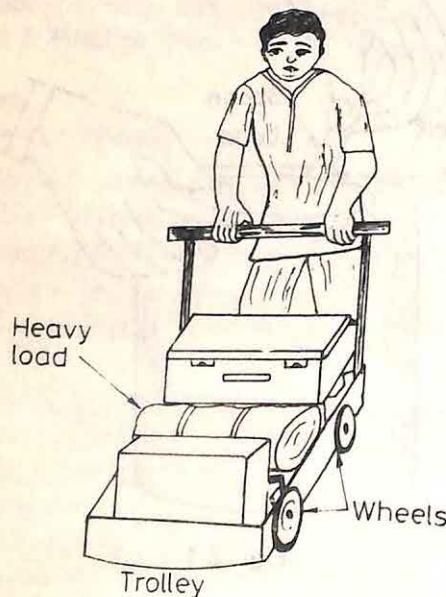


Fig. 2.3

These examples show that a difficult job is made easy if we use a machine to do the job. Thus, a machine is a device which makes a difficult job easy.

### Effort and Load

No machine can work by itself. A force is applied to some part of a machine. This force is called the *input force* or *effort*. This force moves that part through a certain distance. As a result of this some other part of the machine exerts a force. This force is called the *output force* or *load* (Fig. 2.4).

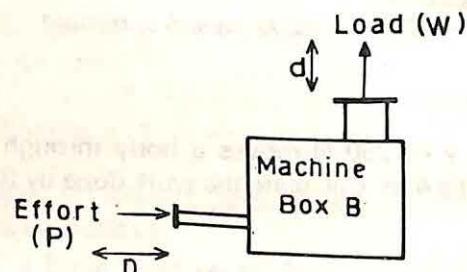


Fig. 2.4

In this chapter we shall learn about a few *basic* or *simple* machines such as lever, wheel, inclined plane, screw and pulley. In most of these machines, the load (output force) is greater than the effort (input force). In other machines, however, the load is equal to the effort but the load acts in a desired direction or in a convenient manner.

Thus, a machine is a device which enables us to exert a force greater than the force applied to it or to exert a force in a convenient direction.

### Mechanical Advantage of a Machine

The main purpose of a machine is to lift a heavy load (or exert a large force) when a small effort (or input force) is applied to it. The mechanical advantage of a machine is the

ratio of the load (or output force) and the effort (or input force).

$$\text{Mechanical advantage} = \frac{\text{Load}}{\text{Effort}}$$

The smaller the effort required to lift a certain load, the greater the mechanical advantage of the machine. The factor by which a machine multiplies the effort is the mechanical advantage of the machine.

### Efficiency of a Machine

Let us say that the box B in Fig. 2.4 represents a machine. Let an effort ( $P$ ) (input force) be applied at a certain part of the machine which moves it through a distance  $D$ . Let the output force (called load) be  $W$  and let us say that it moves a load through a distance  $d$ . Then

$$\text{Work done on the machine} = \text{input force} \times \text{distance moved} = P \times D$$

$$\text{Work done by the machine} = \text{output force} \times \text{distance moved} = W \times d$$

If no work is wasted or lost, the work done on the machine must be equal to the work done by the machine or

$$P \times D = W \times d$$

$$\text{or Effort} \times \text{Effort arm} = \text{Load} \times \text{load arm}$$

This is the principle on which a machine works. A machine in which no work is wasted is called an *ideal* or *perfect* machine. No machine is perfect because some part of work is always lost in overcoming friction between the moving parts of a machine. Hence the useful work done by a machine is always less than the total work done on the machine.

*The efficiency of a machine is the ratio of the useful work done by a machine and the total work done on the machine.*

Efficiency =

$$\frac{\text{Useful work done by a machine}}{\text{Total work done on the machine}}$$

In an ideal or perfect machine, no work is wasted and all the input work is converted into useful work. In other words, the efficiency of an ideal machine is unity (or 100 per cent). The efficiency of an actual machine is always less than 1 or less than a 100 per cent.

### EXAMPLE 3

In a machine, an effort of 5 N moving through 5 cm moves the load through a distance of 1 cm exerting a force of 20 N. Calculate the mechanical advantage and efficiency of the machine.

#### Solution

$$\text{Effort } (P) = 5 \text{ N}, \text{ Distance moved by effort } (D) = 5 \text{ cm} = 0.05 \text{ m}$$

$$\text{Load } (W) = 20 \text{ N}, \text{ Distance moved by load } (d) = 10 \text{ cm} = 0.01 \text{ m}$$

Mechanical advantage

$$= \frac{\text{Load}}{\text{Effort}} = \frac{20 \text{ N}}{5 \text{ N}} = 4$$

Work done on the machine

$$= P \times D = 5 \text{ N} \times 0.05 \text{ m} = 0.25 \text{ J}$$

Work done by the machine

$$= W \times d = 20 \text{ N} \times 0.01 \text{ m} = 0.2 \text{ J}$$

Efficiency

$$= \frac{\text{Work done by the machine}}{\text{Work done on the machine}} = \frac{0.2 \text{ J}}{0.25 \text{ J}} = 0.8 \text{ or } 80 \text{ per cent}$$

### Levers

*A lever is a rod which can turn about a fixed point called the fulcrum.* When a force (called effort) is applied at one point on the lever, a force (called load) is exerted at another point. Levers are divided into three classes depending on the position of the fulcrum, effort and load.

### Levers of First Class

The levers in which the fulcrum is between the effort and the load are called levers of first class. A see-saw is an example of lever of first class. On a see-saw a small boy can easily balance a big boy (Fig. 2.5). This is possible

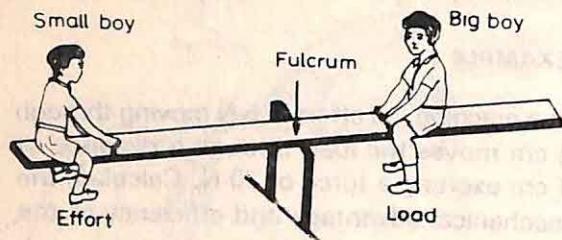


Fig. 2.5

if the big boy sits near the fulcrum and the small boy sits away from the fulcrum. The small boy exerts the effort and the big boy is the load which is lifted up. Thus, if the distance of the effort from the fulcrum is more than that of the load from the fulcrum, a little effort can lift a big load. This type of lever reduces considerably the effort we have to put in to do the job.

Other examples of levers of first class are: spoon to open the lid of a tin (Fig. 2.1); crow bar; pliers; scissors; handle of a hand pump; hand brake of a bicycle.

Figure 2.6 shows a few levers of first class.

### Levers of Second Class

The levers in which the load is between the fulcrum and the effort are called levers of second class. The fulcrum is at one end and the load is closer to the fulcrum than the effort. This lever also reduces the effort that we have to put in to do the job.

Examples of levers of second class are: nut cracker; wheelbarrow; lemon squeezer; foot bellows; mango cutter.

Figure 2.7 shows a few levers of second class.

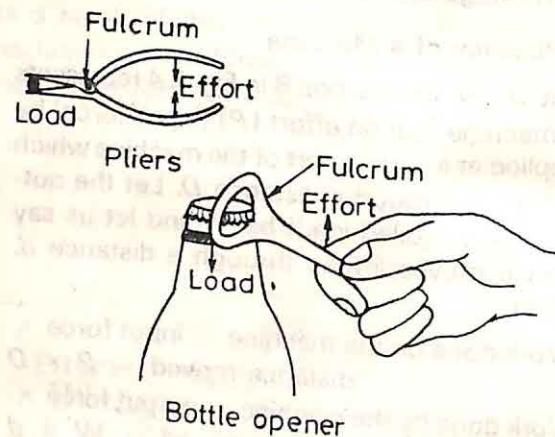
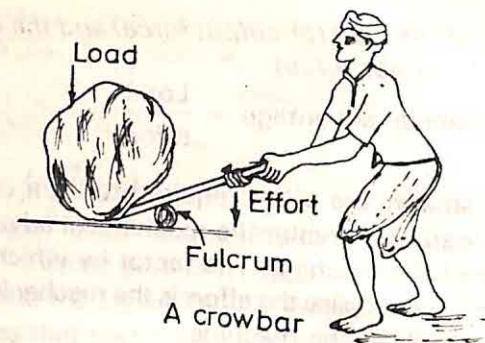


Fig. 2.6

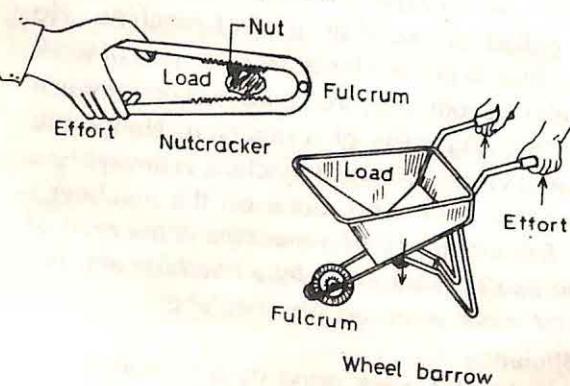
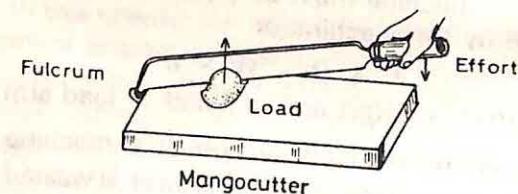


Fig. 2.7

### Levers of Third Class

The levers in which the effort is between the fulcrum and the load are called levers of third class. The fulcrum is at one end, but the effort is closer to the fulcrum than the load. In these levers the output force (load) is less than the input force (effort). In spite of this disadvantage, these levers are useful for lifting tiny objects or objects that cannot be touched by hand such as a piece of burning coal.

The examples of levers of third class are: a pair of tongs; forearm of a person holding a load; a knife used to slice bread.

Figure 2.8 shows levers of third class.

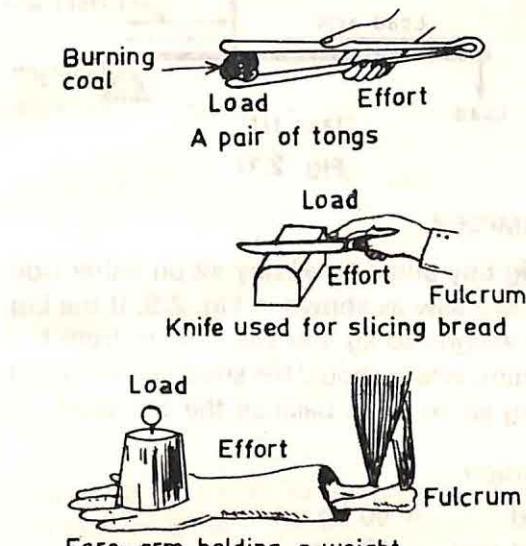


Fig. 2.8

### Activity 1

Take an iron rod and tie a heavy load (such as bag containing 5 kg of rice) at one end of the rod. Place the rod on your shoulder, holding the other end A of the rod as shown in Fig. 2.9. Start with load as near your shoulder as possible and your hands as far away from the shoulder as possible. Do you

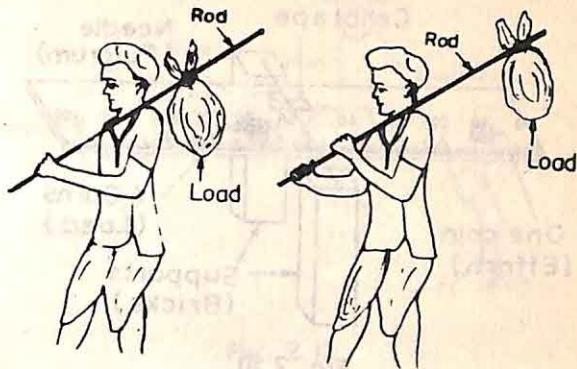


Fig. 2.9

feel that you can hold the load with very little effort?

Now slide the rod over your shoulder, thus increasing the distance between the load and the shoulder and decreasing the distance between your hand and the shoulder. What do you find? Is it difficult to hold or carry the load now?

\_\_\_\_\_

\_\_\_\_\_

### Activity 2

Take a long rod and use it as a crowbar to lift a heavy box in your house.

\_\_\_\_\_

\_\_\_\_\_

### Activity 3

You will need a metre scale, a knitting needle, two bricks, cellotape or plasticine and a number of 25 paise coins.

Tape the needle to the centre of the metre scale and place it on two bricks as shown in Fig. 2.10. The scale will balance on the needle. If it does not, use tiny bits of plasticine to balance it.

Use four coins as the load and place them 10 cm from the fulcrum. Find out where you should keep a single coin on the other side of the fulcrum in order to balance this load. Measure the distance between the coin and

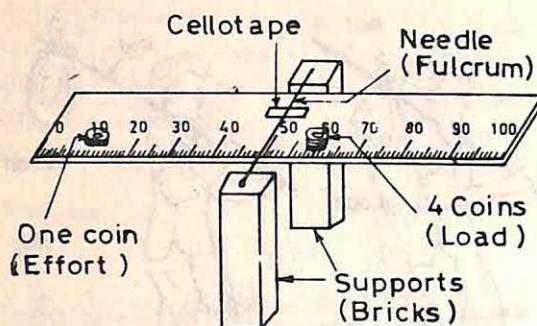


Fig. 2.10

the fulcrum. Use the weight of one coin as a unit of load. Calculate load  $\times$  load arm and effort  $\times$  effort arm. The effort is the weight of one coin.

Repeat your experiment using two coins and four coins as the effort. You will find that, in each case,

$$\text{Load} \times \text{load arm} = \text{Effort} \times \text{effort arm}$$

Since  $\text{load} \times \text{load arm} = \text{effort} \times \text{effort arm}$ , the mechanical advantage of a lever is given by

Mechanical advantage =

$$\frac{\text{Load}}{\text{Effort}} = \frac{\text{Effort arm}}{\text{Load arm}}$$

Now look at Fig. 2.6 which shows levers of first class. Notice that the effort arm is greater than the load arm. In other words, the mechanical advantage of levers of the first class is greater than 1. Figure 2.7 shows that the mechanical advantage of levers of second class is also greater than 1. But the mechanical advantage of levers of third class is less than 1 (see Fig. 2.8) because the effort arm is less than the load arm. Although there is a mechanical disadvantage in using levers of the third class, these levers are useful in lifting tiny objects or objects which cannot be touched by hand such as a piece of burning coal.

Figure 2.11 shows how the three kinds of levers can be represented in a diagram.

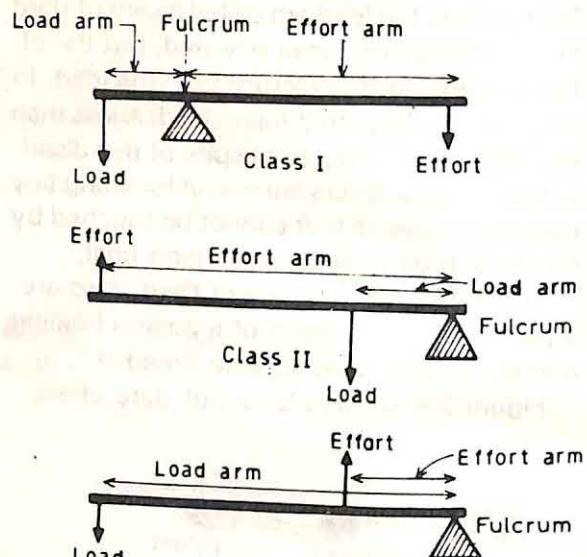


Fig. 2.11

#### EXAMPLE 4

A big boy and a small boy sit on either side of a see-saw as shown in Fig. 2.5. If the big boy weighs 50 kg and sits 120 cm from the fulcrum, where should the small boy weighing 30 kg sit so as to balance the see-saw?

*Solution*

$$\text{Load} = 50 \text{ kg wt}$$

$$\text{Load arm} = 120 \text{ cm}$$

$$\text{Effort} = 30 \text{ kg wt}$$

$$\text{Effort arm} = ?$$

Now  $\text{Effort} \times \text{effort arm} = \text{Load} \times \text{load arm}$   
 or  $30 \text{ kg wt} \times \text{effort arm} = 50 \text{ kg wt} \times 120 \text{ cm}$

$$\text{Effort arm} =$$

$$\frac{50 \text{ kg wt} \times 120 \text{ cm}}{30 \text{ kg wt}} = 200 \text{ cm}$$

#### EXAMPLE 5

A crowbar of length 1 metre shown in Fig.

2.12 is used to lift a load of 90 N by placing a fulcrum at a distance of 10 cm from it and

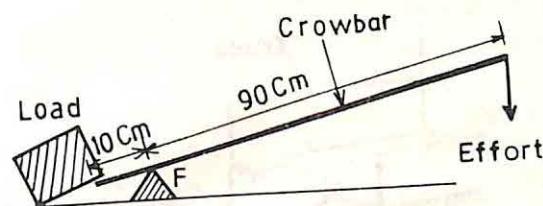


Fig. 2.12

applying an effort at the other end as shown. What is the mechanical advantage of the lever and how much effort is needed to just lift the load?

*Solution*

$$\text{Load} = 90 \text{ N}$$

$$\text{Load arm} = 10 \text{ cm}$$

$$\text{Effort arm} = 90 \text{ cm}$$

$$\text{Mechanical advantage} =$$

$$\frac{\text{Effort arm}}{\text{Load arm}} = \frac{90 \text{ cm}}{10 \text{ cm}} = 9$$

$$\text{Now effort} \times \text{effort arm} = \text{load} \times \text{load arm}$$

$$\text{effort} = \frac{\text{load} \times \text{load arm}}{\text{effort arm}}$$

$$= \frac{90 \text{ N} \times 10 \text{ cm}}{90 \text{ cm}} = 10 \text{ N}$$

Thus an effort of only 10 N will be needed to lift a load of 90 N.

## Pulleys

The pulley is a simple machine which is used for lifting loads. You must have seen a person lifting a bucket full of water from a well using a pulley. A pulley consists of a circular disc made of metal or wood which can rotate about an axle passing through its centre. It has a groove cut along its rim so that a string can pass round it. The ends of the axle are supported on a frame known as the block as shown in Fig. 2.13 (a).

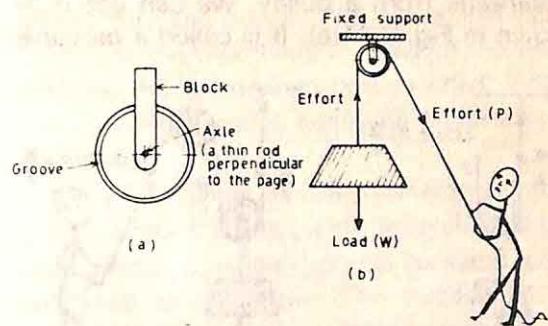


Fig. 2.13

The load is attached to one end of a string which passes over the pulley and the effort is applied at the other end as shown in Fig. 2.13(b). It is clear from the diagram that effort ( $P$ ) to be applied must be equal to the load to be lifted.

$$W = P$$

Therefore, mechanical advantage =

$$\frac{\text{Load} (W)}{\text{Effort} (P)} = 1$$

In other words, there is no mechanical advantage in the use of this pulley. This is true only for a perfect or ideal pulley. In an actual pulley the mechanical advantage is less than 1 because a part of the effort is used up in overcoming the friction in the pulley. In other words, the effort is more than the load and, therefore, there is a mechanical disadvantage. Then why do we use the pulley? The reason is that it is much easier to apply a force in a downward direction than in an upward direction because we can use our own weight in order to apply effort. The main advantage of the pulley is that it allows us to *apply the force in a convenient direction*.

The pulley described above is called a *fixed pulley*. Its block is attached to a fixed support. No mechanical advantage is gained in this pulley. If we wish to gain a mechanical

advantage from a pulley, we can use it as shown in Fig. 2.14(a). It is called a *movable pulley*.

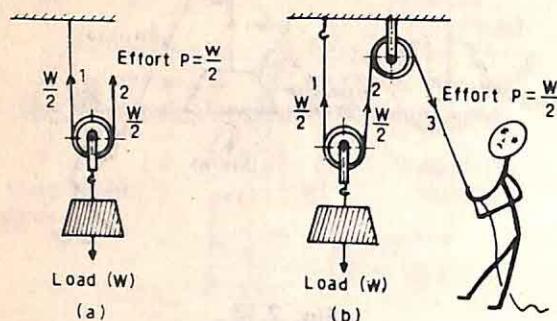


Fig. 2.14

**pulley.** The load to be lifted is attached to the block of the pulley. One end of the string is fixed to a support and the effort is applied at the other end.

Now the load  $W$  is distributed over the strings 1 and 2. The string 1 which is fixed at one end takes up half the load. Hence the effort ( $P$ ) to be applied to lift the load is only  $\frac{W}{2}$

Thus

$$P = \frac{W}{2}$$

$$\therefore \text{Mechanical advantage} = \frac{W}{P} = 2$$

In other words, in order to lift a load of 50 kg wt, an effort of only 25 kg wt is needed. However, now the effort has to be applied in an upward direction because the string 2 has to be pulled upwards. This is inconvenient. This can be avoided by combining the movable pulley with a fixed pulley as shown in Fig. 2.14 (b). The fixed pulley simply changes the direction of the effort; it enables us to apply the necessary effort of 25 kg wt in a *convenient direction* to lift a load of 50 kg wt.

### The Inclined Plane

Suppose you wish to load a heavy drum full

of cement on a truck. Lifting the drum and putting it on the truck will be extremely difficult. Now look at Fig. 2.15 and observe how

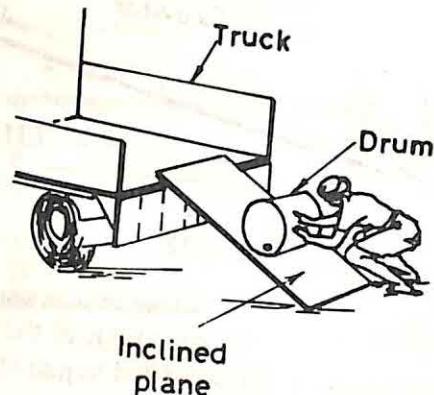


Fig. 2.15

the man is trying to put the drum on the truck. He is using a sloping surface (a wooden plank). It is easier to push the drum along the sloping surface than to lift it up vertically.

*A sloping surface is called an inclined plane.* The word *inclined* means *sloping*.

You must have seen people pushing a scooter, motor cycle or bicycle along the ramp (inclined plane) provided in a building. Tall buildings and hospitals are provided with ramps to help people climb up or carry loads.

Let us find out how much easier it is to carry a load along an inclined plane than to lift it up vertically. Using a spring balance find out the weight of a wooden block (see Fig. 2.16 a). Now place the block on an inclined

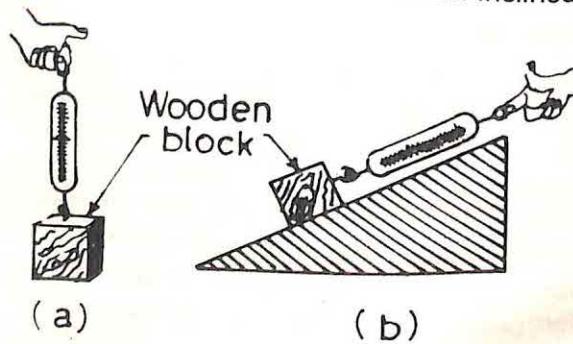


Fig. 2.16

plane. With a spring balance find out how much force is needed to support the block on the inclined plane, so that the block does not slip down. This force will be less than the weight of the block (Fig. 2.16 b). If the inclined plane is less steep, the force needed to support the block on it is found to decrease, making it easier to carry along the inclined plane.

Staircases in buildings are also an example of the use of an inclined plane. Steps are provided on an inclined plane to make a staircase.

### The Screw

You must have seen a carpenter using screws and bolts to hold things together. A screw is made by cutting spiral grooves on the surface of a metal rod. The spiral ridges so formed are called the *threads* of the screw (Fig. 2.17a).

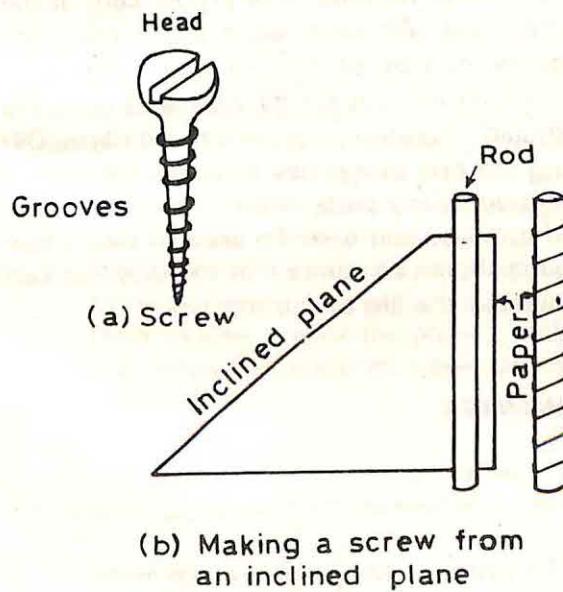


Fig. 2.17

Take a screw and try to drive it into a block of wood by hammering it on its head with a hammer. You will find it very hard to drive the screw. Now, with the help of a screw driver,

simply turn the screw. The screw will easily drive into the wood and its hold on the wood is better than that of an ordinary nail. It cannot be pulled out as easily as a nail can be pulled out.

Why is it easier to drive the screw with a screw driver than by hammering it? The reason is that a screw has an inclined plane wrapped round a rod. The threads of the screw are like a ramp in a circular form. It is something like a circular staircase. Figure 2.17b shows how a screw can be obtained from an inclined plane by simply winding an inclined plane around a rod or a pencil.

### Screw Jack

You must have seen a motor mechanic using a jack to lift a car. The jack uses the principle of screw. It is called screw jack. It is used to lift heavy vehicles like cars, buses and trucks (Fig. 2.18).

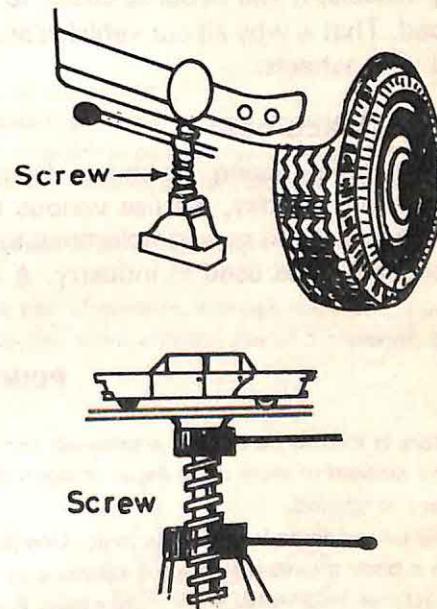
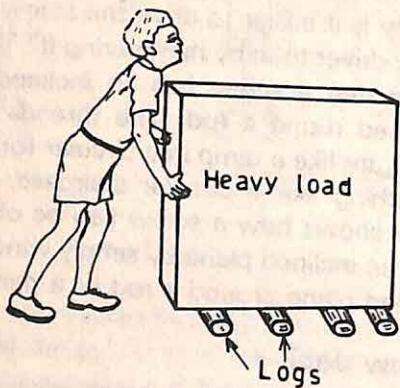


Fig. 2.18

### Wheel

Wheel is one of the earliest and the most im-

portant inventions of man. Suppose you wish to push a heavy load on a road. You will find it very hard to do so as it requires a lot of effort to push a very heavy load. Now push a few cylindrical logs under the load (Fig. 2.19).



Complicated machine is a combination of a few simple machines such as the lever, inclined plane; screw, pulley, wheel. Look carefully at your bicycle and find out how many simple machines it has.

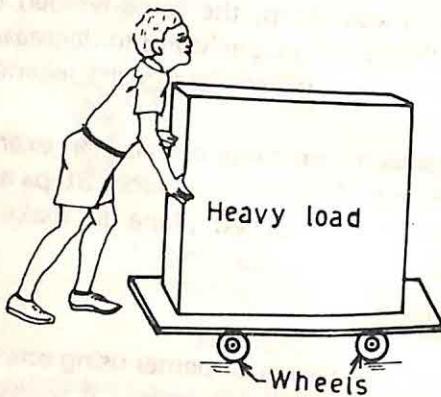


Fig. 2.19

You will find that the load can now be easily pushed over the logs. If the logs are replaced by wheels, it will become easier to push the load. That is why all our vehicles are provided with wheels.

### Care of Machines

Man has been using machines from the earliest times. Today, we use various types of machines; from very simple ones to very complicated ones used in industry. A com-

Machines are used for convenience. Therefore, we must take proper care of the machines. We have learnt that friction opposes motion of the moving parts of a machine and causes its wear and tear. We should, therefore, lubricate these parts. Oiling the axle of a pulley or wheel will reduce friction. Many parts of a machine are made of iron and can rust. To prevent this, these parts should be painted. In this way, we can increase the life of the machines.

### POINTS TO REMEMBER

1. Work is said to be done if a force applied to a body produces motion.
2. The amount of work done depends upon the magnitude of the force and the distance through which the force is applied.
3. The unit of force is called the joule. One joule of work is said to be done if a force of one newton acting on a body moves it through a distance of 1 metre in the direction of the force.
4. Machines help us do work more easily. A machine is a device which enables us to exert a force greater than the force applied to it or to exert a force in a convenient direction.
5. The mechanical advantage of a machine is the ratio of the load (or output force) and the effort (or input force).
6. The efficiency of a machine is the ratio of the useful work done by the machine and the total work done on the machine.

Levers are simple machines most commonly used. Levers are of three classes. Class 1 levers have a fulcrum (*F*) between load (*L*) and effort (*E*). In class 2 levers, the load is between fulcrum and effort and in class 3 levers, the effort is between load and fulcrum. You can memorize it as follows:

*F, L and E*

Each in the centre be

Make levers of class one, two and three.

8. A single fixed pulley is used for lifting a load by applying the effort in a convenient direction. There is no mechanical advantage in the use of single fixed pulley. Mechanical advantage is gained in a movable pulley; the effort applied is less than the load.
9. A sloping surface is called an inclined plane. It is easier to carry a load along an inclined plane than to lift it vertically upward.
10. We use machines for convenience. Therefore, we should take proper care of our machines.

### QUESTIONS

1. (a) What is the meaning of the term *work*?  
 (b) State the factors on which the work done by a force on a body depends.  
 (c) State and define a unit of work.  
 (d) Does a person do any work if he carries a suitcase and  
     (i) stays motionless,  
     (ii) walks on a horizontal surface, and  
     (iii) climbs up a hill?  
 (e) A force of 100 N moves a body through of distance of 50 cm. Calculate the work done by the force and state its unit.
2. (a) What is a machine?  
 (b) What is the principle on which a machine works?  
 (c) Define the terms mechanical advantage and efficiency of a machine.  
 (d) Can a machine have an efficiency of 100 per cent? State the reason for your answer.  
 (e) In a machine a force of 20 N is applied to the input button which is pushed inward through a distance of 20 cm. The output platform moves through 2 cm exerting a force of 150 N. Calculate the mechanical advantage and efficiency of the machine.
3. (a) Describe the three classes of levers giving one example of each. Draw neat diagrams showing the position of the fulcrum, load and effort.  
 (b) Name the class to which the following levers belong: a pair of scissors, a lemon squeezer, a pair of sugar tongs, a claw hammer, a beam balance, a fishing rod, a nut cracker, oar of a rowboat, and a bicycle brake.

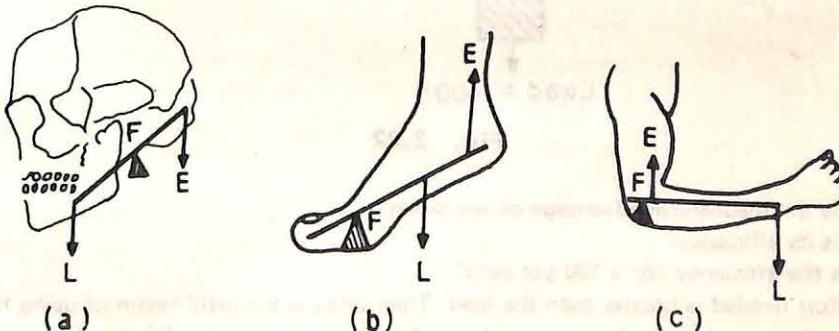


Fig. 2.20

(c) The human body is a complex machine. Figure 2.20 shows three levers found in a human body. To which class does each lever belong? What job does each lever perform?

(d) The effort arm of a lever is 5 m long and its load arm is 2 m long. Find the effort needed to raise a load of 75 kg wt. What is the mechanical advantage of the lever?

4. A man applies a force of 50 kg wt to a crowbar in order to lift a boulder weighing 500 kg wt. If the effort arm is 100 cm long, what should be the distance of the fulcrum from the boulder?

5. Figure 2.21 shows a nutcracker with a fixed base. Study the diagram and answer the following questions:

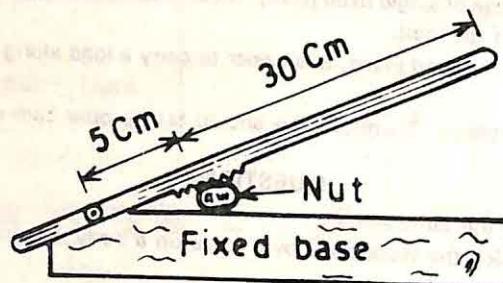


Fig. 2.21

(i) Where are the fulcrum, load and effort? Copy this diagram and mark the labels *F*, *L* and *E*.

(ii) To what class does this lever belong?

(iii) What is the mechanical advantage of the lever?

6. Figure 2.22 shows a fixed pulley. Study the diagram and answer the following questions.

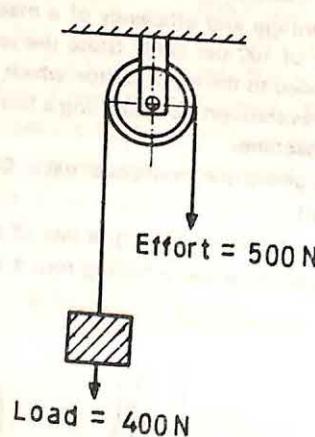


Fig. 2.22

(i) What is the mechanical advantage of the pulley?

(ii) What is its efficiency?

(iii) Why is the efficiency not a 100 per cent?

(iv) The effort needed is greater than the load. Then what is the justification of using the pulley?

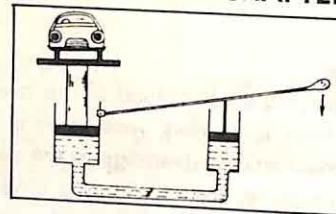
(v) Draw a diagram showing how a movable pulley is attached to the fixed pulley in order to increase mechanical advantage.

7. *Mark true or false*

- (i) A labourer carrying a heavy load on his head and walking on a level road does not do any work.
- (ii) Whenever a force is exerted, work is done by the force.
- (iii) There is no mechanical advantage in the use of a single fixed pulley.
- (iv) In an actual machine, the efficiency is always greater than a 100 per cent.
- (v) The mechanical advantage of levers of class three is greater than unity.
- (vi) The mechanical advantage of a machine is always greater than unity.
- (vii) The mechanical advantage of a machine may have any value from a small fraction to a large number.
- (viii) It is easier to lift a load vertically upward than to push it along an inclined plane.

8. *Fill in the blanks using the choices given in brackets*

- (i) If a force of 10 N moves a body through a distance of 10 cm, the work done by the force is \_\_\_\_\_ (1 J, 10 J, 100 J).
- (ii) The unit of force is the \_\_\_\_\_ and the unit of work is \_\_\_\_\_ (joule, newton).
- (iii) In levers of class 2, the \_\_\_\_\_ lies between the \_\_\_\_\_ and \_\_\_\_\_ (fulcrum, effort, load).
- (iv) The useful work done by a machine is always \_\_\_\_\_ the total work done on the machine. (equal to, more than, less than).
- (v) A single fixed pulley is used to \_\_\_\_\_ (increase the effort, increase the load, apply force conveniently).



# Pressure in Liquids and Gases

## What is Pressure?

Consider a book lying on a table. The weight of the book exerts a downward force on the table. This force acts over a certain area of the table. The area over which the force acts is equal to the area of the face of the book in contact with the table. The force acting on a surface is called *thrust*.

The term *pressure* is used to measure and describe the effect of a force acting on a surface. *The effect of a force depends on the area upon which it acts.* Try the following simple experiment and find out for yourself.

### Activity 1

Take a heavy book and balance it on the palm

of your hand as shown in Fig. 3.1a. Now try to balance the same book on a small pencil as shown in Fig. 3.1b. Why is it painful to balance the book on a pencil? The force acting on your palm in both cases is the same, equal to the weight of the book. In the first case this force is spread over the larger area of your palm. In the second, the same force is concentrated over a very small area, the area of the tip of the pencil. Thus a force has a different effect if it acts over a different area.

In the language of science, we say that, in the second case, the pressure is greater than in the first case.

*Pressure is defined as the force or thrust exerted per unit area.*

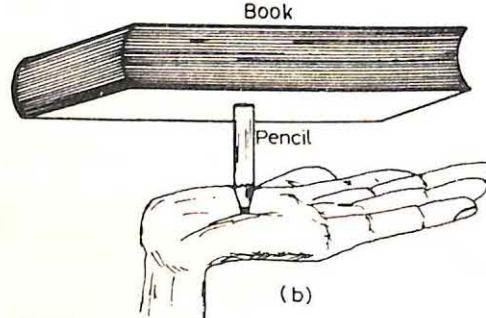
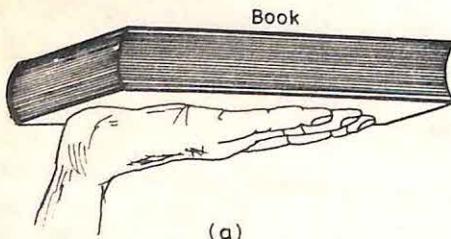


Fig. 3.1

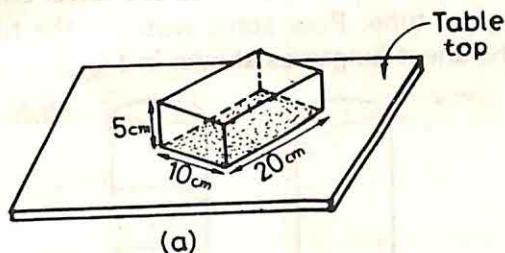
That is, Pressure =  $\frac{\text{Force or thrust}}{\text{Area}}$

It is clear that the smaller the area over which a force acts, the greater the pressure.

### Unit of Pressure

In the MKS system, force is measured in newton (N) and area is square metre ( $\text{m}^2$ ). Therefore, in the MKS system, the unit of pressure is *newton per square metre* ( $\text{N/m}^2$ ).

Let us calculate the pressure exerted by a brick on a table. Figure 3.2 shows a brick of



(a)

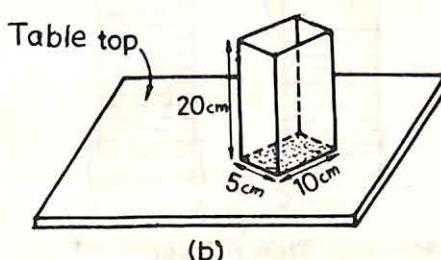


Fig. 3.2

dimensions  $20 \text{ cm} \times 10 \text{ cm} \times 5 \text{ cm}$  lying on a table. In Fig. 3.2a the brick is lying on its side and in Fig. 3.2b the same brick is standing on end. What is the pressure exerted by the brick in each case?

Suppose the mass of the brick is 5 kg. It exerts a force of

$$5 \text{ kg} \times 9.8 \text{ m/s}^2 = 49 \text{ N}$$

on the surface.

In case (a) the area over which this force acts

$$= 20 \text{ cm} \times 10 \text{ cm}$$

$$= 200 \text{ cm}^2 \\ = 0.02 \text{ m}^2$$

Hence, it exerts a pressure of

$$\frac{49 \text{ N}}{0.02 \text{ m}^2} = 2450 \text{ N/m}^2$$

In case (b) the same force of 49 N now acts over an area  $= 10 \text{ cm} \times 5 \text{ cm}$   
 $= 50 \text{ cm}^2$   
 $= 0.005 \text{ m}^2$

Hence, it exerts a pressure of

$$\frac{49 \text{ N}}{0.005 \text{ m}^2} = 9800 \text{ N/m}^2$$

Thus, the same force acting on a smaller area exerts a larger pressure.

The pressure exerted by a body can be reduced by increasing its surface area. Therefore, the base of walls of a building is made wider to reduce pressure exerted by the building (Fig. 3.3). Can you now tell why

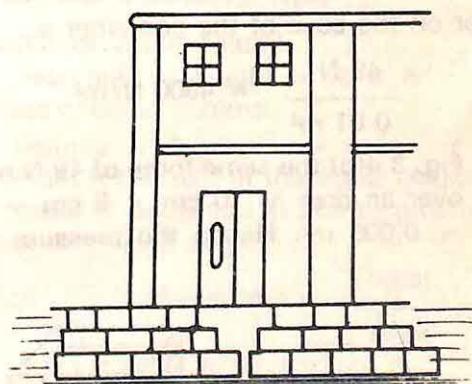


Fig. 3.3

heavy animals such as elephants and camels have broad feet?

Sometimes, in order to increase the effect of a force, it is necessary to decrease the area over which it acts. In order to obtain maximum pressure with a minimum force, many appliances such as knives, nutcrackers,

scissors, nails, etc., are made with very sharp edges. Can you now tell why it is easier to cut with a sharp knife than with a blunt one?

### Pressure in Liquids

Unlike a solid, a liquid does not have a definite shape. It takes the shape of the vessel in which it is contained. Hence, while dealing with liquids, it is more meaningful to use the concept of pressure rather than thrust or force.

Like solids, liquids also exert pressure on the vessel in which they are contained. Let us calculate the pressure exerted by a liquid at the bottom of the container. Take equal mass of water, say 5 kg, in two containers as shown in Fig. 3.4. The force exerted by 5 kg of water

$$= 5 \text{ kg} \times 9.8 \text{ m/s}^2 = 49 \text{ N}$$

In Fig. 3.4(a) the force of 49 N is exerted over an area  $= 20 \text{ cm} \times 5 \text{ cm} = 100 \text{ cm}^2 = 0.01 \text{ m}^2$ . Hence the pressure exerted by water on the base of the container is

$$\frac{49 \text{ N}}{0.01 \text{ m}^2} = 4900 \text{ N/m}^2$$

In Fig. 3.4(b) the same force of 49 N now acts over an area  $= 10 \text{ cm} \times 5 \text{ cm} = 50 \text{ cm}^2 = 0.005 \text{ m}^2$ . Hence the pressure ex-

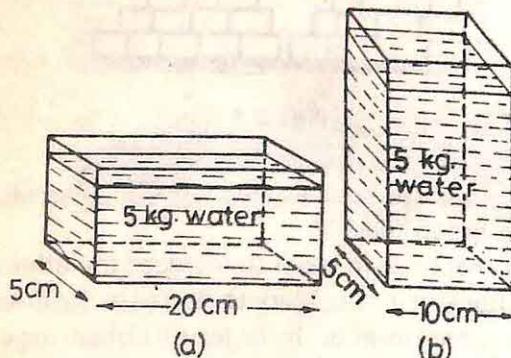


Fig. 3.4

erted by water on the base of the container in this case is

$$\frac{49 \text{ N}}{0.005 \text{ m}^2} = 9800 \text{ N/m}^2$$

Thus water, in these two cases, exerts the same force but not the same pressure at the bottom of the container.

### Factors on which Liquid Pressure Depends

What are the factors on which the pressure at a depth in a liquid depends? Let us find out.

Tie a thin rubber sheet at the lower end of a glass tube. Pour some water in the tube. The sheet bulges as shown in Fig. 3.5. Add

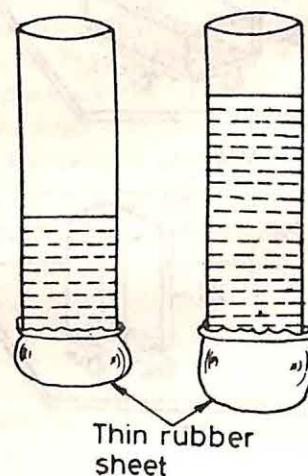


Fig. 3.5

more water. The sheet bulges more. This shows that the force exerted by water at the bottom of its container depends on the height of the water column. The greater the height the greater the force. If the force exerted by the water is  $W$  (equal to the weight of the liquid column) and the area of the rubber sheet is  $A$ , then the pressure  $P$  exerted by the liquid is given by

$$P = \frac{W}{A}$$

Since the force  $W$  increases with the height of the liquid column, it is clear that the pressure also increases with the height of the liquid column.

Now take two identical glass tubes having their lower ends closed with identical thin rubber sheets. Pour water in tube A and mustard oil in tube B so that the heights of the liquid columns are equal in the two tubes (see Fig. 3.6). You will notice that the sheet bulges out

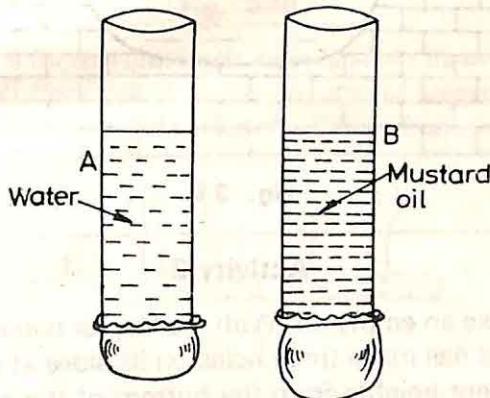


Fig. 3.6

more in the tube containing mustard oil than in the tube containing water.

Since the heights of liquid columns in the two tubes are equal and the tubes are identical, the volumes of the two liquids are also equal. But the density of mustard oil is more than that of water. Now mass = density  $\times$  volume. Hence the mass (and therefore the weight) of mustard oil in tube B is more than that of water in tube A. Therefore, mustard oil exerts greater pressure than water.

Thus we conclude that the pressure at a depth in a liquid depends upon two factors:

1. the height of the liquid column. The greater the height, the greater the pressure.
2. the density of the liquid. The greater the density the greater the pressure.

### The Pressure-Depth Formula

Consider a liquid column of height  $h$  contained in a cylindrical tube of base area  $A$  as shown in Fig. 3.7. Let  $d$  be the density of the liquid. The pressure at the bottom of the con-

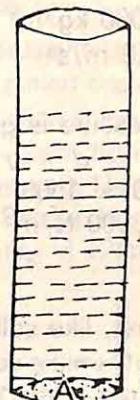


Fig. 3.7

tainer is equal to the force per unit area of the liquid column above it. Now

Volume of liquid column

$$= \text{base area} \times \text{height} = A \times h$$

$\therefore$  Mass of liquid column

$$= \text{volume} \times \text{density} = A \times h \times d$$

$\therefore$  Weight (or thrust) of the liquid column

$$= \text{mass} \times \text{acceleration due to gravity}$$

$$= A \times h \times d \times g$$

$$\text{Hence} \quad \text{Pressure} = \frac{\text{Thrust}}{\text{Area}}$$

$$= \frac{A \times h \times d \times g}{A}$$

$$= h \times d \times g$$

$$\text{or } P = h \times d \times g$$

This is the pressure-depth formula. If the height  $h$  is expressed in metres density  $d$  in  $\text{kg/m}^3$  and acceleration due to gravity  $g$  in  $\text{m/s}^2$ , then pressure  $P$  is obtained in  $\text{N/m}^2$ .

#### EXAMPLE 1

Calculate the pressure at the bottom of a lake

10 m deep. The density of water is  $1000 \text{ kg/m}^3$  and acceleration due to gravity is  $9.8 \text{ m/s}^2$ .

**Solution**

$$h = 10 \text{ m}$$

$$d = 1000 \text{ kg/m}^3$$

$$g = 9.8 \text{ m/s}^2$$

$$p = ?$$

The pressure is given by

$$\begin{aligned} P &= h \times d \times g \\ &= 10 \times 1000 \times 9.8 \\ &= 98000 \text{ N/m}^2 \end{aligned}$$

### Lateral Pressure

You have seen that, like solids, liquids also exert pressure. But, unlike solids, liquids exert pressure not only at the bottom but also on the sides of the vessel in which they are contained.

Take a tube having an opening in its side. Cover the opening with a thin rubber sheet. When the tube is filled with water, the sheet bulges as shown in Fig. 3.8. Add more water.

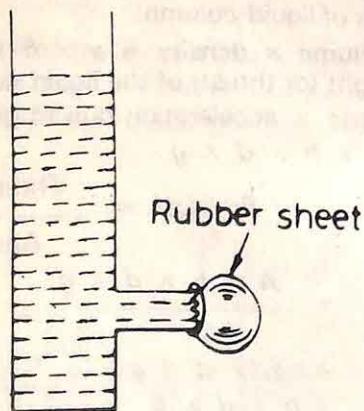


Fig. 3.8

The sheet bulges more. The reason is that the depth of water column, and hence the pressure has increased. This experiment shows that a liquid exerts pressure on the wall

of its container and the sideways pressure (called lateral pressure) increases with depth.

It is for this reason that the walls of the water reservoir of a dam have to be made thicker at the bottom (Fig. 3.9).

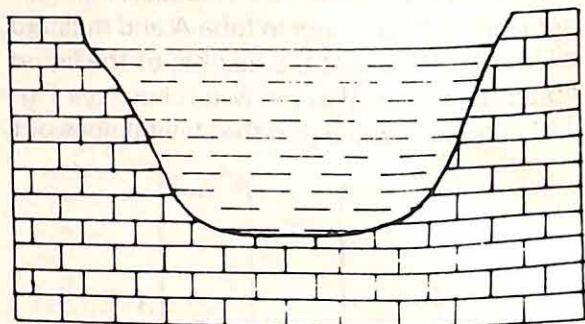


Fig. 3.9

### Activity 2

Take an empty tin. With the help of hammer and nail make three holes on its sides at different heights from the bottom of the can. Plug the holes with plasticine. Fill the can completely with water. Remove the plasticine from the bottom hole and collect the water coming out for 1 minute. Repeat the experiment and collect water coming out from the other holes for the same time. Is the amount of water collected from different holes the same? What conclusions will you draw from your observations?

### Pressure in a Liquid Acts Equally in all Directions

This fact can be demonstrated by using a tall cylindrical jar having holes of the same size and at the same depth. Plug the holes with stoppers and fill the jar with water. Remove the stoppers. Jets of water will emerge from the hole with the same force (Fig. 3.10). Since the size (or area) of the holes is the same, the equality of force implies equality of pressure.

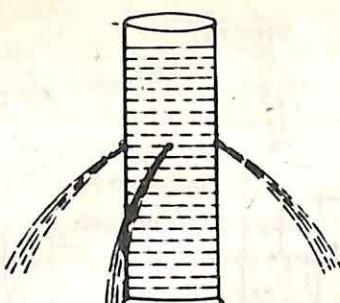


Fig. 3.10

It is for this reason that *liquid seeks its own level*. Pour some water in one of vessels shown in Fig. 3.11. Water will flow from this

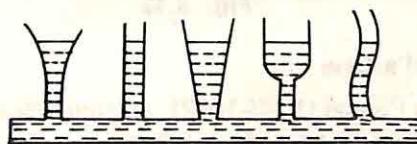


Fig. 3.11

vessel into all other vessels until the pressure in each vessel is equalised and the liquid stands at the same height in each vessel. The water level in each vessel will be the same irrespective of the size or shape of the vessels. That is why water tanks are built at heights greater than the height of the tallest building.

### Atmospheric Pressure

Like liquids, gases also exert pressure. The atmosphere of the earth is a mixture of gases. Near the surface of the earth, air is made up of about 78% nitrogen, 21% oxygen and a very small amount of other gases. Due to the pull of the gravity, these gases tend to collect near the surface of the earth. The air becomes thinner and thinner as we go up. Near the surface of the earth the density of air is about  $1.3 \text{ kg/m}^3$ .

Like all gases, air also has weight and hence it exerts pressure. The air in an average living room weighs over a 100 kg. Just as water

pressure is caused by the weight of water, the weight of all the air above the earth exerts the *atmospheric pressure*.

### Measurement of Atmospheric Pressure: The Simple Barometer

Atmospheric pressure is measured with the help of a device called the *barometer*. It was invented by an Italian scientist E. Torricelli in 1643. He took a glass tube about 1 m long and closed at one end. He filled it completely with mercury. Placing his finger at the open end as shown in Fig. 3.12(a), he inverted the

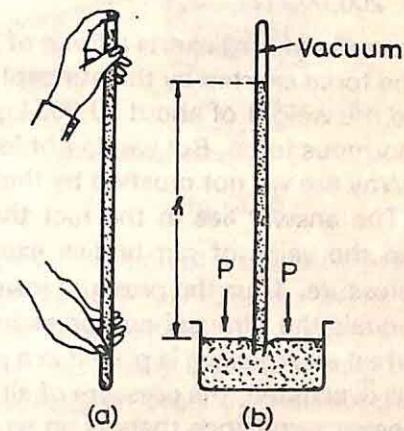


Fig. 3.12

tube and dipped the open end (with the finger firmly placed over it) in a dish containing mercury, as shown in Fig. 3.12(b). The finger was then removed.

The mercury level begins to drop gradually, ultimately settling to a vertical height  $h$  as shown. This height is measured.

The value of  $h$  is about 76 cm (or 0.76 m) at sea-level. The atmospheric pressure is the pressure due to a column of 0.76 m of mercury. Thus, atmospheric pressure

$$\begin{aligned}
 &= \text{pressure due to } 0.76 \text{ m of mercury column} \\
 &= h \times d \times g \\
 &= 0.76 \text{ m} \times 13600 \text{ kg/m}^3 \times 9.8 \text{ m/s}^2 \\
 &= 100,000 \text{ N/m}^2
 \end{aligned}$$

Instead of expressing the pressure in  $\text{N/m}^2$ , it is customary to give the height of mercury column. Thus, the atmospheric pressure is 76 cm (or 0.76 m) of mercury.

Thus, all the air above the earth exerts a pressure of 100,000  $\text{N/m}^2$  on the earth's surface and on the surface of all objects on the earth including living beings. The surface area of an average human being is about  $2\text{m}^2$ . Therefore, the total force exerted on his body by the atmosphere

$$\begin{aligned} &= \text{atmospheric pressure} \times \text{area} \\ &= 100,000 \text{ N/m}^2 \times 2 \text{ m}^2 \\ &= 200,000 \text{ N} \end{aligned}$$

Since, a mass of 1 kg exerts a force of about 10 N; the force exerted by the atmosphere is equal to the weight of about 20,000 kg. This is an enormous force. But we do not feel this force. Why are we not crushed by this huge force? The answer lies in the fact that the blood in the veins of our bodies exerts an equal pressure. Thus the pressure inside the veins equals the atmospheric pressure outside. When an organism is placed in a jar and the jar is evacuated, the pressure of air in the jar becomes zero (since there is no air left in the jar). The veins of the organism actually explode due to its internal pressure.

### The Crushing Can Experiment

The enormous magnitude of atmospheric pressure can be demonstrated by the so-called *crushing can experiment* illustrated in Fig. 3.13. Pour some water in a metallic can and heat it (without the cap) until water begins to boil. When the steam starts coming out of the opening, put the cap back and remove the can from the burner. Steam has forced most of the air out of the can. Now pour cold water on the can. The steam condenses into water, leaving a partial vacuum in the can. What happens to the can? It is crushed by the pressure of the air outside.

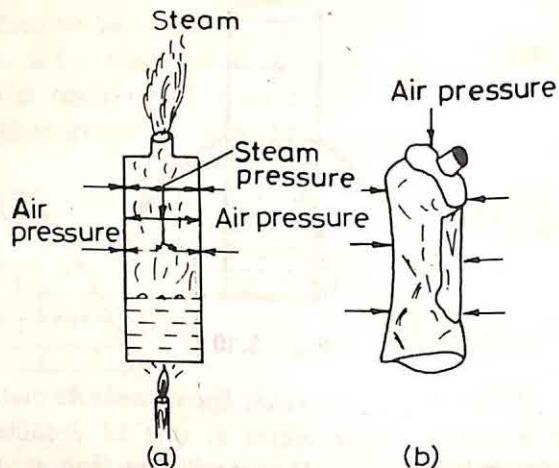


Fig. 3.13

### Pascal's Law

Blaise Pascal (1623-1662), a French scientist, discovered a law which tells us how force can be transmitted in a liquid or gas. It is known as *Pascal's law* which states that *when pressure is applied to an enclosed liquid or gas, it is transmitted equally in all directions*.

Figure 3.14 shows a glass flask having small

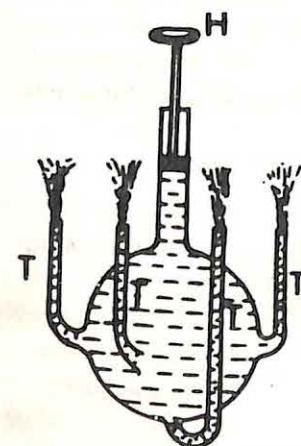


Fig. 3.14

tubes (T) jutting out from the side as well as the bottom of the flask. The flask is filled with water and is fitted with a piston which can

be pushed down by applying a force at the handle ( $H$ ). When the piston is pushed down, jets of water are seen to rise to the same height. This experiment shows that the pressure applied to the liquid is transmitted equally in all directions.

**Applications of Pascal's Law: Hydraulic Machines** Hydraulic machines such as the hydraulic press, hydraulic brakes and hydraulic jack are devices that are based on Pascal's law of transmission of pressure in liquids. The principle on which a hydraulic machine works is as follows: Consider two cylindrical tubes of cross-sectional areas  $A_1$  and  $A_2$  connected by a horizontal tube  $T$  as shown in Fig. 3.15. The apparatus is filled with

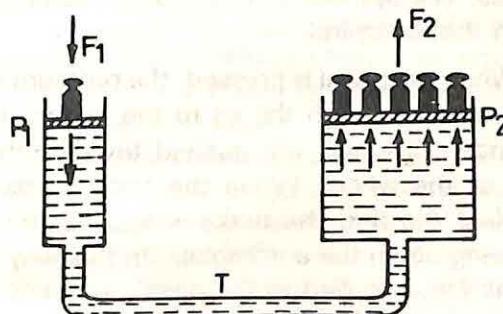


Fig. 3.15

a liquid. The cylinders have watertight pistons  $P_1$  and  $P_2$ . Place a mass on piston  $P_1$ . Let us say that it exerts a force  $F_1$  on piston  $P_1$ . Therefore, the pressure exerted on piston  $P_1$  =  $F_1/A_1$ .

According to Pascals law, this pressure is transmitted by the liquid to piston  $P_2$ . Thus, the upward pressure exerted on piston  $P_2$  =  $F_1/A_1$ . Therefore, the upward force  $F_2$  exerted on piston  $P_2$

$$= \text{pressure on } P_2 \times \text{area } A_2$$

$$\text{or } F_2 = \frac{F_1}{A_1} \times A_2$$

$$\frac{F_2}{F_1} = \frac{A_2}{A_1}$$

If  $A_2 > A_1$  then  $F_2 > F_1$ . Thus a small force  $F_1$  can be used to exert a much larger force  $F_2$ . For example, if  $A_2 = 5A_1$ , then  $F_2 = 5F_1$ . Thus the force is multiplied five times.

**Hydraulic Press:** It is a hydraulic machine which is used for pressing bales of cotton, paper, metal sheets, etc. Figure 3.16 shows

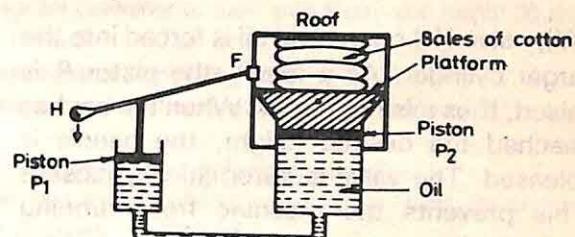


Fig. 3.16

a simplified version of a hydraulic press. The smaller piston  $P_1$  is called the *pump plunger* and the larger piston  $P_2$  is called the *press plunger*. The area of cross-section of the press plunger is much larger than that of the pump plunger. The machine is filled with a liquid. The pump plunger is worked with the help of a lever having its fulcrum at  $F$  and the effort is applied at the handle  $H$ . The bales of cotton to be pressed are placed between the platform of the press plunger and the roof of the machine.

**Hydraulic Jack** The hydraulic jack is used for lifting heavy loads such as cars or other heavy objects. The principle of its working is the same as that of a hydraulic press. Figure 3.17 shows a simple hydraulic jack. The effort is applied to the smaller piston  $P_1$  and the car is placed on the platform of the larger piston  $P_2$ . The whole apparatus is filled with oil. When an effort is applied at the handle

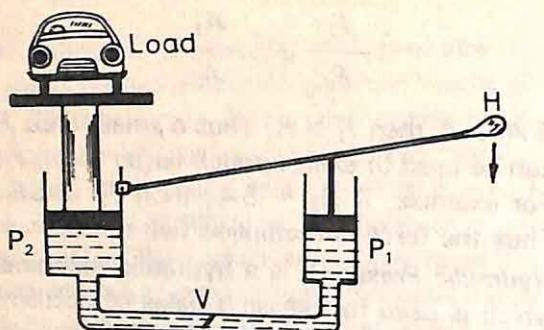


Fig. 3.17

(H), valve (V) opens and oil is forced into the larger cylinder. As a result, the piston  $P_2$  is raised, thus raising the car. When the car has reached the desired height, the handle is released. The valve is automatically closed. This prevents the machine from running backwards.

**Hydraulic Brake** Hydraulic brakes are also based on the principle of transmission of pressure in a liquid. These brakes are used in automobiles. Figure 3.18 shows the essential parts of a braking device used in automobiles. It consists of a tube  $T$  containing oil. One end of this tube is connected to a cylinder  $C_1$ , fit-

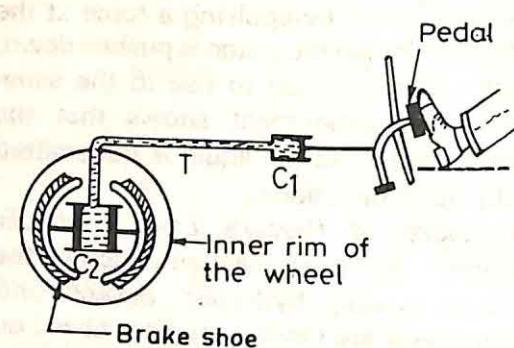


Fig. 3.18

ted with a piston which is connected to the pedal as shown. The other end of the tube is connected to a cylinder  $C_2$  having two pistons which are connected to the brake shoes. The cylinder  $C_2$  has a larger diameter than that of cylinder  $C_1$ .

When the pedal is pressed, the pressure is transmitted through the oil to the pistons in cylinder  $C_2$  which are pushed towards the rim of the wheel. When the shoe presses against the rim, the brake is applied, thus slowing down the automobile. In this way a small force applied to the pedal produces a much larger stopping force.

#### POINTS TO REMEMBER

1. The total force acting on a surface is called thrust.
2. Pressure is defined as the force or thrust exerted per unit area. In the MKS system, the unit of pressure is newton per square metre ( $N/m^2$ ).
3. The pressure at a depth in a liquid depends upon the height of the liquid column and the density of the liquid. The pressure  $P$  at a depth  $h$  in a liquid of density  $d$  is given by

$$P = h \times d \times g$$

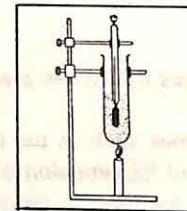
where  $g$  is the acceleration due to gravity.

4. Liquids and gases exert pressure not only at the bottom but also on the sides of the vessel in which they are contained.
5. Pressure in a liquid acts equally in all directions.
6. The atmospheric pressure is due to the weight of the air above the earth. At sea-level, the atmospheric pressure is 76 cm or 0.76 m of mercury. In MKS units, its value is about  $100,000 N/m^2$ .
7. The atmospheric pressure at a place is measured with a device called the barometer.

- Pascal's law states that *when pressure is applied to an enclosed liquid or gas, it is transmitted equally in all directions.*
- Hydraulic machines such as the hydraulic press, hydraulic jack and hydraulic brake are devices based on Pascal's law of transmission of pressure in liquids.
- These machines are used to produce a large output force using a small input force.

### QUESTIONS

- Define the terms thrust and pressure. State their units in MKS system.
- (a) What are the factors on which the pressure exerted by a liquid depends?  
(b) Describe a simple experiment to show that the pressure in a liquid depends on (i) depth and (ii) density of the liquid.  
(c) Derive the pressure-depth formula for a liquid.  
(d) Calculate the pressure at the bottom of a cylindrical container of base area  $5 \text{ cm}^2$  and height 20 cm when filled completely with water. Take  $g = 10 \text{ m/s}^2$ .
- (a) Describe an experiment which shows that a liquid exerts lateral pressure.  
(b) Describe an experiment to show that the pressure in a liquid acts equally in all directions.
- (a) What is atmospheric pressure due to?  
(b) Describe the simple barometer. How is it used to measure atmospheric pressure?  
(c) The atmospheric pressure at a place is 75 cm of mercury. Calculate the pressure in  $\text{N/m}^2$ . Density of mercury =  $13600 \text{ kg/m}^3$  and acceleration due to gravity =  $10 \text{ m/s}^2$ .  
(d) Describe an experiment which shows that atmosphere exerts a very high pressure.
- (a) State Pascal's law.  
(b) What is a hydraulic machine? Describe the principle on which it works.  
(c) Draw a labelled diagram of a hydraulic press and explain how it works.
- Find the pressure at a depth of 20 m in a lake. Take  $g = 10 \text{ m/s}^2$ .
- A rectangular tank is 10 m long, 5 m broad and 2 m deep. What will be the thrust and pressure at the bottom if it is half-full of water? Take  $g = 10 \text{ m/s}^2$ .
- A measuring cylinder of height 30 cm and internal diameter 10 cm is filled completely with water. Calculate the pressure at the bottom of the cylinder.
- Give reasons for the following
  - A dam has broader walls at the bottom than at the top.
  - It is easier to cut with a sharp knife than with a blunt one.
  - Deep-sea divers have to use a special outfit.
  - We do not feel uneasy even under enormous atmospheric pressure.
  - A balloon collapses when air is removed from it.
- Fill in the blanks using the choices given in brackets*
  - The pressure at a point in a liquid is directly proportional to \_\_\_\_\_ and \_\_\_\_\_ (mass, weight, depth, density).
  - The MKS unit of thrust is \_\_\_\_\_ and of pressure is \_\_\_\_\_ ( $\text{N}$ ,  $\text{N/m}$ ,  $\text{N/m}^2$ ).
  - The atmospheric pressure is approximately equal to \_\_\_\_\_  $\text{N/m}^2$ . ( $1$ ,  $10^3$ ,  $10^5$ ,  $10^7$ ).
  - Pressure  $\times$  area = \_\_\_\_\_ (thrust, density, depth).
  - A hydraulic machine multiplies \_\_\_\_\_ (pressure, force, work, energy).



# Measurement of Heat

It is a good idea to recall what you have already learnt about heat and its effects. One of the most obvious effects of heating a substance is a *rise in its temperature*. If a substance absorbs heat, its temperature rises; if it loses heat, its temperature falls. You already know how a substance absorbs (or gains) heat or gives out (or loses) heat. When a hot body is brought into contact with or exposed to a colder body; heat flows from the body at a higher temperature to a body at a lower temperature. You know that this transfer of heat can take place by three processes called conduction, convection and radiation. You are also familiar with another important effect of heat called the thermal expansion of substances.

In this chapter you will study how heat is measured and will learn about another very important effect of heat—melting and boiling.

## Measurement of Heat

If a pan of water is placed on the fire, heat flows from the fire to the pan and then to the water, raising their temperatures. How much heat flows from fire to pan and water? To answer this question, it is necessary to examine the factors on which the quantity of heat absorbed by a body depends. Let us perform the following experiments and find out.

### EXPERIMENT 1

Take two identical beakers A and B. Pour 1 kg of tap water in beaker A and 2 kg of tap water in beaker B. Record the temperature of water in each beaker; it is the same. Let it be  $30^{\circ}\text{C}$ . Now put the beakers on identical electric heaters and find the time taken for the temperature to increase to, say,  $50^{\circ}\text{C}$ . You will find that the time taken by water in beaker B to be heated from  $30^{\circ}\text{C}$  to  $50^{\circ}\text{C}$  is twice the time taken by water in beaker A to be heated through the same range of temperature. When the time is doubled, the heat supplied by the heater is also doubled. Thus we *conclude that the quantity of heat absorbed by a body depends on its mass for given rise in temperature*.

### EXPERIMENT 2

Take a beaker and pour some water in it. Record the temperature of water. Let it be  $30^{\circ}\text{C}$ . Place the beaker on a heater and find the time taken to raise the temperature of water to  $50^{\circ}\text{C}$  (a temperature rise of  $20^{\circ}\text{C}$ ). Next find the time required to raise the temperature of the same quantity of water from  $30^{\circ}\text{C}$  to  $70^{\circ}\text{C}$  (a temperature rise of  $40^{\circ}\text{C}$ ). You will find that the time taken in the second case is twice that in the first case. This experiment shows that *the amount of heat ab-*

sorbed by a body depends upon the rise in temperature.

From these experiments we conclude that the amount of heat required to raise the temperature of a given substance depends upon its mass and the raise in temperature.

### Unit of Heat

We need a unit of heat to find out how much heat is required to heat a certain mass of substance to a certain temperature. A unit of heat commonly used is called the *calorie* (symbol cal).

*One calorie is the amount of heat required to raise the temperature of one gram of water through one degree celsius.* This means that 10 calories of heat will be required to heat 10 grams of water through  $1^{\circ}\text{C}$  or 1 gram of water through  $10^{\circ}\text{C}$ . Similarly 100 calories of heat are required to raise the temperature of 10 grams of water through  $10^{\circ}\text{C}$ .

A bigger unit of heat is called the *kilocalorie* (symbol kcal). One kilocalorie is equal to 1000 calories. In other words, *one kilocalorie is the amount of heat required to raise the temperature of 1 kg (or 1000 g) of water through  $1^{\circ}\text{C}$ .*

### EXAMPLE 1

How many kilocalories of heat are needed to heat 400 g of water from  $35^{\circ}\text{C}$  to  $50^{\circ}\text{C}$ ?

*Solution*

$$\text{Mass of water} = 400 \text{ g}$$

$$\text{Rise in temperature} = 50 - 35 = 15^{\circ}\text{C}$$

Amount of heat needed to raise the temperature of 1 g of water through  $1^{\circ}\text{C}$  = 1 calorie. Therefore, the amount of heat required to raise the temperature of 400 g of water through  $15^{\circ}\text{C}$ .

$$\begin{aligned} &= 400 \times 15 \\ &= 6000 \text{ calories} \\ &= 6 \text{ kilocalories} \end{aligned}$$

### Specific Heat

Will equal masses of different substances require the same amount of heat when they are heated through the same range of temperature? Let us find out.

Take two identical beakers, one containing water and the other an equal mass of kerosene. Before heating, the temperature of water is equal to that of kerosene. Let it be  $30^{\circ}\text{C}$ . Put the beakers on identical electric heaters. Record the time taken for the temperature of each liquid to rise to  $50^{\circ}\text{C}$ . You will find that kerosene heats up much more quickly than water. It takes about half the time for kerosene to heat from  $30^{\circ}\text{C}$  to  $50^{\circ}\text{C}$  than for the same mass of water to heat from  $30^{\circ}\text{C}$  to  $50^{\circ}\text{C}$ . If you perform similar experiments with different substances you will find that *equal masses of different substances require different amounts of heat to be heated through the same range of temperature.*

In the language of physics, we say that different substances have different *specific heats*. *The specific heat of a substance is the amount of heat required to raise the temperature of one gram of the substance through  $1^{\circ}\text{C}$ .*

The unit of specific heat is *calorie per gram per degree celsius* (cal/g/ $^{\circ}\text{C}$ ) or *kilocalorie per kilogram per degree celsius* (kcal/kg/ $^{\circ}\text{C}$ ).

To heat 1 g of water through  $1^{\circ}\text{C}$  the amount of heat required is 1 cal. Thus the specific heat of water is  $1 \text{ cal/g}/^{\circ}\text{C}$ . You may also say that specific heat of water is 1 kcal/kg/ $^{\circ}\text{C}$  which means that 1 kcal of heat is required to heat 1 kg of water through  $1^{\circ}\text{C}$ . Thus.

$$1 \text{ cal/g}/^{\circ}\text{C} = 1 \text{ kcal/kg}/^{\circ}\text{C}$$

Scientists have measured specific heats of various substances. The value of specific heat of some common substances is given below:

Name of the substance	Specific heat in cal/g/°C
Water	1.00
Aluminium	0.21
Copper	0.09
Iron	0.11
Lead	0.03
Ice	0.05
Kerosene	0.51

The specific heat of copper is 0.09 cal/g/°C. This means that in order to heat 1 g of copper through 1°C, only 0.09 calorie of heat is required. Similarly 1 g of kerosene requires 0.51 cal (about half a calorie) of heat to be heated through 1°C. It is for this reason that a given mass of kerosene heats up about twice as fast as the same mass of water.

#### EXAMPLE 2

How much heat is needed to raise the temperature of 50 g of iron from 25°C to 45°C? The specific heat of iron = 0.11 cal/g/°C.

*Solution*

$$\text{Mass of iron} = 50 \text{ g}$$

$$\text{Rise in temperature} = 45-25 = 20^\circ\text{C}$$

The specific heat of iron is 0.11 cal/g/°C. This means that in order to raise the temperature of 1 g of iron through 1°C, the amount of heat needed = 0.11 cal. Therefore, in order to raise the temperature of 50 g of iron through 20°C, the amount of heat needed

$$\begin{aligned} &= 0.11 \times 50 \times 20 \\ &= 11 \text{ cal} \end{aligned}$$

#### EXAMPLE 3

How much heat is required to raise the temperature of 400 g of kerosene from 10°C

to 35°C? The specific heat of kerosene = 0.51 kcal/kg/°C.

*Solution*

$$\text{Mass of kerosene} = 400 \text{ g} = 0.4 \text{ kg}$$

$$\text{Rise in temperature} = 35 - 10 = 25^\circ\text{C}$$

In order to raise the temperature of 1 kg of kerosene through 1°C, the amount of heat required is 0.51 kcal. Therefore, in order to raise the temperature of 0.4 kg kerosene through 25°C, the amount of heat required =  $0.51 \times 0.4 \times 25$  = 5.1 kcal

From these examples it is clear that the total amount of heat required is obtained by multiplying together the mass of the substance, its specific heat and the raise in temperature.

$$\text{Amount of heat} = \text{mass} \times \text{specific heat} \times \text{rise in temperature}$$

If a substance absorbs (or gains) heat, its temperature rises. What happens if a substance is cooled? It gives out (or loses) heat when it cools. The amount of heat given out or lost by a substance on cooling is obtained by multiplying together its mass, its specific heat and the fall in temperature.

#### EXAMPLE 4

If the specific heat of vegetable oil is 0.47 cal/g/°C, how much heat is given out when 400 g of the oil cools from 100°C to 40°C?

*Solution*

$$\begin{aligned} \text{Amount of heat given out} &= \text{mass} \times \text{specific heat} \times \text{fall in temperature} \\ &= 400 \times 0.47 \times 60 \\ &= 11280 \text{ cal} \end{aligned}$$

$$\text{Heat Lost} = \text{Heat Gained}$$

What happens when you mix hot water with cold water in a plastic bucket? The final temperature of water in the bucket is lower

than the temperature of the hot water but higher than the temperature of the cold water. The hot water gives out heat which is taken up by the cold water. The flow of heat stops when all the water in the bucket is at the same temperature which we call the final or *equilibrium temperature*. The following actual experiment reveals a very important principle concerning the flow of heat. 100 g of water at 80°C is mixed with 50 g of water at 20°C in a well-insulated non-conducting plastic tumbler. The final temperature of the mixture is found to be 60°C. Let us find out how much heat is exchanged between hot and cold water.

$$\text{Mass of hot water} = 100 \text{ g}$$

$$\text{Initial temperature of hot water} = 80^\circ\text{C}$$

$$\text{Final temperature of the mixture} = 60^\circ\text{C}$$

$$\begin{aligned}\text{Fall in temperature of hot water} &= 80 - 60 \\ &= 20^\circ\text{C}\end{aligned}$$

Heat given out (or lost) by hot water

$$\begin{aligned}&= \text{mass} \times \text{specific heat} \times \text{fall in temperature} \\ &= 100 \times 1 \times 20 = 2000 \text{ cal}\end{aligned}$$

$$\text{Mass of cold water} = 50 \text{ g}$$

$$\text{Initial temperature of cold water} = 20^\circ\text{C}$$

$$\begin{aligned}\text{Rise in temperature of cold water} &= 60 - 20 \\ &= 40^\circ\text{C}\end{aligned}$$

$$\begin{aligned}\text{Heat taken up (or gained) by cold water} &= \text{mass} \times \text{specific heat} \times \text{rise in temperature} \\ &= 50 \times 1 \times 40 = 2000 \text{ cal}\end{aligned}$$

What do you find? Heat lost = heat gained.

*When a hot body is brought into contact with a cold body, the heat lost by the hot body is equal to the heat gained by the cold body.*

The following example shows how the specific heat of a substance can be measured.

#### EXAMPLE 5

A piece of copper of mass 500 g is heated to 100°C and then placed in 210 g of water at 15°C in a non-conducting vessel. The final temperature is found to be 30°C. Calculate the specific heat of copper.

#### Solution

$$\text{Mass of copper} = 500 \text{ g}$$

$$\begin{aligned}\text{Fall in temperature of copper} &= 100 - 30 \\ &= 70^\circ\text{C}\end{aligned}$$

If the specific heat of copper is  $s \text{ cal/g}/^\circ\text{C}$ , the heat lost by copper = mass  $\times$  specific heat  $\times$  fall in temperature

$$= 500 \times s \times 70 = 35000 \text{ s cal}$$

$$\text{Mass of water} = 210 \text{ g}$$

$$\begin{aligned}\text{Rise in temperature of water} &= 30 - 15 \\ &= 15^\circ\text{C}\end{aligned}$$

$$\text{Specific heat of water} = 1 \text{ cal/g}/^\circ\text{C}$$

$$\begin{aligned}\text{Heat gained by water} &= \text{mass} \times \text{specific heat} \\ &\quad \times \text{rise in temperature} \\ &= 210 \times 1 \times 15 \\ &= 3150 \text{ cal}\end{aligned}$$

$$\text{But Heat lost} = \text{heat gained}$$

$$\text{or } 35000 \text{ s} = 3150$$

$$3150$$

$$s = \frac{3150}{35000} = 0.09 \text{ cal/g}/^\circ\text{C}$$

#### EXAMPLE 6

What is the final temperature of the mixture if 100 g of hot water at 70°C is mixed with 200 g of cold water at 10°C?

#### Solution

Let the final temperature of the mixture be  $t^\circ\text{C}$ .

$$\text{Heat lost by hot water} = 100 \times 1 \times (70 - t)$$

$$\text{Heat gained by cold water} = 200 \times 1 \times (t - 10)$$

$$\text{But Heat lost} = \text{heat gained}$$

$$\text{or } 100 \times (70 - t) = 200 \times (t - 10)$$

$$\text{or } 70 - t = 2 \times (t - 10)$$

$$\text{or } 70 - t = 2t - 20$$

$$\text{or } 3t = 90$$

$$\text{or } t = 30^\circ\text{C}$$

#### Change of State

When substances are heated, there are three effects:

(i) rise in temperature

- (ii) expansion or an increase in size
- (iii) change in the state of the substances.

You have already learnt about the first two of these effects and know something about the third effect. You know that when a solid is heated, it changes into a liquid and on further heating, the liquid changes into a gas. When ice is heated, it changes into water. On further heating, water changes into steam. You will now learn more about these changes.

### Melting and Solidification

The change from the solid state to the liquid state on heating is called *melting*. Let us find out what happens when a solid is melting. Take some wax in a boiling tube and heat it over a flame as shown in Fig. 4.1. The temperature of the wax is recorded every minute.

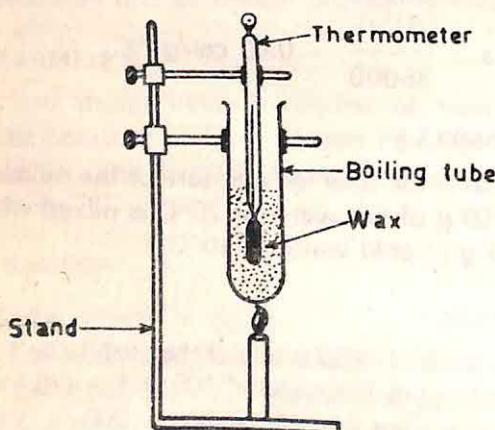


Fig. 4.1

Here are the readings obtained in one such experiment.

Time (in minutes)	1	2	3	4	5	6	7	8	9	10	11	12
Temperature of wax (in °C)	35	40	45	50	55	55	55	55	60	65	70	75

These readings are plotted on a graph paper as shown in Fig. 4.2 which tells you how the temperature of wax changes with time as it

is heated. Do you notice anything peculiar in these reading? Up to 4 min the temperature of wax increases. Between 5 min and 8 min the temperature does not rise, it remains constant at 55°C, although the wax is being

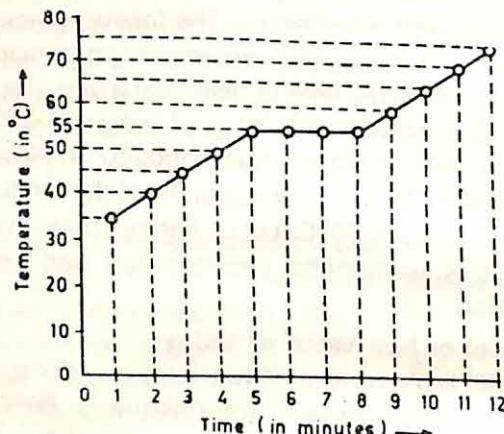


Fig. 4.2

heated all the time. After 8 min, the temperature rises again.

What happens to the heat which is not recorded by the thermometer between 5 min and 8 min? During this time the solid wax was *melting and changing into liquid wax*. While the wax was melting, it was still being heated, but its temperature did not rise. The heat supplied by the flame was being used to change solid wax into liquid wax. This heat which is not recorded by the thermometer is called *hidden or latent heat*. The word *latent* means *hidden*. The constant temperature at which solid wax changes into liquid wax is called its

*melting point*. The readings and the graph shown in Fig. 4.2 show that the melting point of wax is 55°C. When all the wax is melted,

the temperature of liquid wax starts rising as is indicated by the last four readings.

*Every substance has a definite melting point.* For example, ice melts at  $0^{\circ}\text{C}$ , naphthalene melts at  $80^{\circ}\text{C}$ , lead melts at  $327^{\circ}\text{C}$  and iron melts at  $1535^{\circ}\text{C}$ .

*When a substance changes from a solid into a liquid, it does so at a constant and definite temperature called its melting point, and takes up latent heat as long as the change is taking place.*

The reverse happens when a liquid is cooled. The liquid freezes (or solidifies) at its melting point. *The temperature during solidification does not change. The liquid gives out its latent heat in order to freeze to its solid state.*

### Activity 1

Take about 250 g solid ghee in a vessel and insert a thermometer in the ghee. Record the temperature. Now heat the vessel over a flame and record the temperature of ghee every minute for 10 minutes. Plot a graph of temperature against time. From the graph, determine the melting point of ghee. Do you observe that the temperature remains constant until all the ghee has melted? Can you give the reason for this?

Remove the vessel from the flame and allow the molten ghee to cool down. Determine the temperature at which the ghee solidifies. Is this temperature the same as the melting point of ghee?

**Latent Heat of Fusion (or Melting)** Equal masses of different substances require different latent heats in order to melt. In order to measure the latent heats of different substances, scientists use a new term called *latent heat of fusion or melting*.

*The latent heat of fusion or melting of a*

*substance is the amount of heat in calories required to convert 1 gram of the substance from solid to liquid state without change of temperature.* It is expressed *calories per gram (cal/g).*

The latent heat of fusion of ice is 80 cal/g. This means that 80 cal of heat are needed to convert 1 gram of ice into water without change in temperature. This may also be written as 80 kcal/kg which means that 80 kcal of heat are needed to convert 1 kg of ice into water without change in temperature. It is obvious that

$$1 \text{ cal/g} = 1 \text{ kcal/kg}$$

The following table shows measured values of latent heat of fusion of some common substances.

Substance	Latent heat of fusion cal/g or kcal/kg
Mercury	2.8
Lead	5.9
Iron	6.6
Paraffix wax	35
Copper	43
Ice	80

### EXAMPLE 7

How much heat is needed to convert 20 g of ice into water at  $0^{\circ}\text{C}$ ? Latent heat of fusion of ice is 80 cal/g.

**Solution** The latent heat of fusion or melting of ice is 80 cal/g. This means that in order to convert 1 g of ice into water at  $0^{\circ}\text{C}$ , the amount of heat needed is 80 cal. Therefore, to convert 20 g of ice into water at  $0^{\circ}\text{C}$ , the amount of heat needed =  $80 \times 20$   
= 1600 cal.

### EXAMPLE 8

215 kcal of heat are required to melt 5 kg of

copper. What is the latent heat of melting of copper?

**Solution** In order to melt 5 kg of copper the amount of heat required is 215 kcal. Therefore, to melt 1 kg of copper the amount of heat required =  $215/5 = 43$  kcal. This, by definition, is the latent heat of melting of copper. Hence latent heat of melting of copper is 43 kcal per kg.

### Vaporisation and Condensation

The change from liquid state into gaseous or vapour state is called *vaporisation*. Vaporisation can take place in two different ways: (i) boiling and (ii) evaporation. We shall deal with evaporation a little later.

Repeat the experiment shown in Fig. 4.1 by taking some tap water in the boiling tube instead of wax. Record the temperature of water every minute. You will find that the temperature of water rises up to  $100^{\circ}\text{C}$  and remains constant while the heat is still being supplied. At this temperature water begins to boil and changes into steam. *This constant temperature at which a liquid changes into a vapour is called its boiling point.* During vaporisation the liquid takes up the latent heat of vaporisation.

*The latent heat of vaporisation of a substance is the amount of heat in calories required to convert 1 gram of the substance from liquid to vapour state without any change in temperature.*

The latent heat of vaporisation of water is 540 cal/g. This means that 540 cal of heat are needed to convert 1 g of water into steam without change in temperature. You may also say that the latent heat of vaporisation of water is 540 kcal/kg. The latent heat of vaporisation of alcohol is 240 cal/g or 240 kcal/kg and for ether it is 84 cal/g.

On cooling, steam changes (or condenses) into water. During condensation, the

temperature remains constant and vapours give out latent heat in order to condense into the liquid. You know that steam at  $100^{\circ}\text{C}$  causes more severe burns than water at  $100^{\circ}\text{C}$ . The reason is that when steam falls on our body, it condenses into water and to do so it gives out its latent heat to our body. Each gram of steam will give out 540 cal of heat to condense into water at  $100^{\circ}\text{C}$ . That is why burns caused by steam are more severe than those caused by an equal amount of boiling water.

*Evaporation and Latent Heat* There is another process by which a liquid changes into a vapour. This process is called *evaporation*. If a wet cloth is hung on a rope, it dries up after some time. It dries up because water in the cloth evaporates or changes into vapour. On a hot day, the wet cloth dries up much faster than on a cold day. Further, if the cloth is spread out, it dries up faster than if it is folded up.

These observations show that the rate of evaporation depends upon the temperature of the liquid and on the exposed area of the liquid. The rate of evaporation also depends upon the nature of the liquid. Volatile liquids like spirit, ether and perfumes evaporate much faster than water.

It must be clearly understood that evaporation and boiling are different processes. *Boiling takes place at a definite temperature called the boiling point of the liquid but evaporation takes place at all temperatures.*

*The change from liquid state to vapour state that takes place at all temperatures of a liquid is called evaporation.*

Evaporation produces cooling. Put a drop of alcohol or spirit on your palm, if feels cold. Pour some spirit on cotton wool and wrap it round the bulb of a thermometer. The reading of the thermometer quickly falls. These simple experiments show that cooling is produced as a liquid evaporates.

The cooling produced in evaporation is due to the fact that a liquid has latent heat. Whenever a liquid changes into vapour, heat is required in the process. If the heat is not supplied from outside (by a burner), the liquid will take in heat from the surrounding bodies and from the liquid itself in order to evaporate. In the first example mentioned above, the heat is taken from our palm and in the second example heat is taken from the surrounding thermometer, resulting in a fall in temperature.

Water in an earthen pot (*surahi*) cools in summer. The water seeps through the pores in the pot and evaporates. The latent heat required for evaporation is taken from water itself which, therefore, cools.

A strip of wet cloth placed on the forehead of a person having high fever reduces the temperature of his body. The reason is that water, while evaporating, takes in the necessary latent heat from the body, thus lowering the temperature of the body.

#### POINTS TO REMEMBER

1. The amount of heat taken in (or given out) by a body depends upon (i) the mass of the body; (ii) the rise (or fall) in its temperature; and (iii) the material of which the body is made.
2. A commonly used unit of heat is the calorie (cal). A bigger unit is the kilocalorie (kcal). One calorie is the amount of heat required to raise the temperature of 1 g of water through  $1^{\circ}\text{C}$ . One kilocalorie is the amount of heat required to raise the temperature of 1 kg (or 1000 grams) of water through  $1^{\circ}\text{C}$ .

$$1 \text{ kcal} = 1000 \text{ cal}$$

3. The specific heat of a substance is the amount of heat in calories required to raise the temperature of 1 g of the substance through  $1^{\circ}\text{C}$ . It may also be defined as the amount of heat in kilocalories required to raise the temperature of 1 kg of the substance through  $1^{\circ}\text{C}$ .

$$1 \text{ cal/g}/^{\circ}\text{C} = 1 \text{ kcal/kg}/^{\circ}\text{C}$$

4. The amount of heat gained (or lost) by a substance is given by the product of its mass, specific heat and the rise (or fall) in its temperature.
5. When a hot body is brought into contact with a cold body, the heat flows from the hot body to the cold body until their temperatures are equalised. During this process, the heat lost by the hot body = heat gained by the cold body.
6. When a substance is heated, there may be three different effects: (i) a rise in temperature; (ii) an expansion or increase in size; and (iii) a change in the state of the substance.
7. The constant temperature at which a substance changes from the solid state to the liquid state is called its melting point. During melting the substance takes in latent heat in order to melt. During solidification the substance gives out latent heat.
8. The latent heat of fusion or melting of a substance is the amount of heat in calories required to convert 1 g of the substance from solid to liquid state without change in temperature. It is expressed in calories per gram (cal/g). It may also be defined as the amount of heat in kilocalories required to convert 1 kg of a substance from solid to liquid state without change in temperature. It may also be expressed as kilocalories per kilogram (kcal/kg).

$$1 \text{ cal/g} = 1 \text{ kcal/kg}$$

9. The constant temperature at which a substance changes from liquid to vapour state is called its boiling point. During vaporisation, the substance takes in latent heat. During condensation, it gives out latent heat. The latent heat of vaporisation of a substance is the amount of heat in calories (or kilocalories) to convert 1 g (or 1 kilogram) of the substance from liquid to vapour state without change in temperature.

10. The other process by which a liquid changes into a vapour is called evaporation. Evaporation takes place at all temperatures. Evaporation is accompanied by cooling.

### QUESTIONS

1. State the factors on which the amount of heat given out by a body depends.
2. Define a calorie and kilocalorie of heat.
3. (a) What is the specific heat of a substance? State its unit.  
 (b) What is the meaning of the following statements?  
     (i) The specific heat of water is 1 cal/g/°C.  
     (ii) The specific heat of aluminium is 0.21 kcal/kg/°C.  
 (c) How many calories of heat are needed to heat 500 g of water from 30°C to 50°C?  
 (d) How much heat is required to raise the temperature of 50 g of aluminium from 50°C to 90°C? The specific heat of aluminium is 0.21 cal/g/°C.  
 (e) How much heat is given out when 500 g of kerosene is cooled from 50°C to 25°C? The specific heat of kerosene is 0.51 kcal/kg/°C.
4. 80 g of water at 80°C is mixed with 40 g of water at 50°C. Calculate the final temperature of the mixture.
5. The amount of heat required to raise the temperature of 50 g of water by 10°C is the same as that required to raise the temperature of a 500 g block of aluminium by 5°C. Calculate the specific heat of aluminium.
6. Rahul took half-a-litre of water in a beaker and heated it on an electric heater. He recorded the temperature of water after every minute. His readings are given below. Study them and answer the following questions.

Time at start	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min
= 0 minute										
Temperature at start	31°C	37°C	43°C	49°C	55°C	61°C	67°C	73°C	79°C	85°C

- (i) What mass of water did he take?  
 (ii) How much heat did the water absorb in the first minute?  
 (iii) How much heat did the water absorb while its temperature rose from 43°C to 67°C?  
 (iv) What is the total amount of heat absorbed by the water during this experiment?  
 (v) Plot a graph of temperature against time.
7. State the three effects of heat on substances.
8. (a) What do you understand by the term *latent heat*? Why is it so called?  
 (b) Define the latent heat of fusion and state its units.  
 (c) Define the latent heat of vaporisation.  
 (d) What is the meaning of the following statements:  
     (i) The latent heat of fusion of ice is 80 kcal/kg.  
     (ii) The latent heat of vaporisation of water is 540 cal/g.
9. (a) How much heat is needed to melt 5 kg of copper? The latent heat of fusion of copper is 43 cal/g.  
 (b) Describe a simple experiment which shows that evaporation produces cooling.  
 (c) Give two applications of evaporation.

10. Give reasons for the following

- Water in a flat dish evaporates faster than in narrow-mouthed bottle.
- Volatile liquids such as spirit and perfumes are stored in tightly closed containers.
- Ice at  $0^{\circ}\text{C}$  rather than water at  $0^{\circ}\text{C}$  is mixed with tap water to get a cold drink.
- Burns caused by steam are more severe than those caused by boiling water.
- Khas-Khas screens are used in desert coolers.

11. A certain quantity of butter is allowed to cool and its temperature is recorded at regular intervals of time. Figure 4.3 shows the temperature time graph of cooling. Study the graph and answer the following questions.

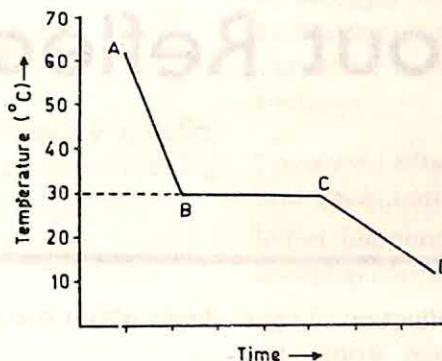
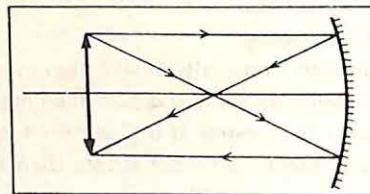


Fig. 4.3

- In what state is the butter between A and B between B and C and between C and D?
- What happens between B and C?
- What is the melting point of butter?

12. Fill in the blanks using the choices given in brackets.

- 1 calorie = \_\_\_\_\_ kilocalorie (1, 1000, 1/1000).
- 5 cal/g/ $^{\circ}\text{C}$  = \_\_\_\_\_ k cal/kg/ $^{\circ}\text{C}$  (5, 5000, 1/5000).
- \_\_\_\_\_ is a unit of specific heat. (cal, kcal, cal/g, cal/g/ $^{\circ}\text{C}$ ).
- \_\_\_\_\_ is a unit of latent heat. (cal, kcal, kcal/kg, cal/g/ $^{\circ}\text{C}$ ).
- Equal masses of kerosene and water at the same initial temperature are heated at the same rates for 5 minutes. The final temperature of kerosene will be \_\_\_\_\_ that of water. (equal to, more than, less than).
- Amount of heat absorbed = mass  $\times$  \_\_\_\_\_  $\times$  rise in temperature (latent heat, specific heat).
- Amount of heat absorbed during a change of state = \_\_\_\_\_  $\times$  latent heat (volume, mass, rise in temperature, specific heat).
- \_\_\_\_\_ takes place at all temperatures but \_\_\_\_\_ takes place at a definite temperature. (boiling, evaporation).



# More about Reflection of Light

Last year you learnt about reflection of light at plane surfaces. You also know the characteristics of images formed by reflection at a plane mirror. When a ray of light is reflected from a mirror, it obeys the following laws of reflection: (Fig. 5.1).

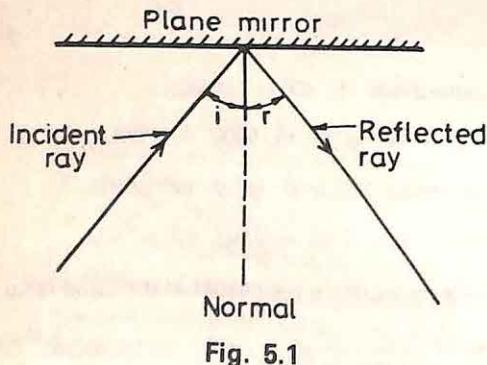


Fig. 5.1

- The angle of incidence is equal to the angle of reflection.*
- The incident ray, the normal at the point of incidence and the reflected ray all lie in the same plane.* (Fig. 5.1). The common plane is the plane of the paper.

In this chapter you will learn how images are formed by spherical mirrors. You will later

learn about the uses of such mirrors.

## Spherical Mirrors

Mirrors need not be plane or flat; they can also be curved. There are various kinds of curved mirrors. The most commonly used curved mirrors are the *spherical mirrors*. A spherical mirror is a part of a hollow sphere or spherical surface. There are two types of spherical mirrors—the *concave mirror* and the *convex mirror*.

A shiny, stainless steel tablespoon is a good example. The inner hollow side of the spoon is a concave mirror; it caves in at the centre. The back surface of the spoon is a convex mirror; it bulges out at the centre.

A concave mirror is made by silvering the back of a concave glass surface as shown in Fig. 5.2(a). A convex mirror is made by silvering the back of a convex glass surface as shown in Fig. 5.2(b).

## Definition of Terms Used in Spherical Mirrors

In order to discuss the formation of images

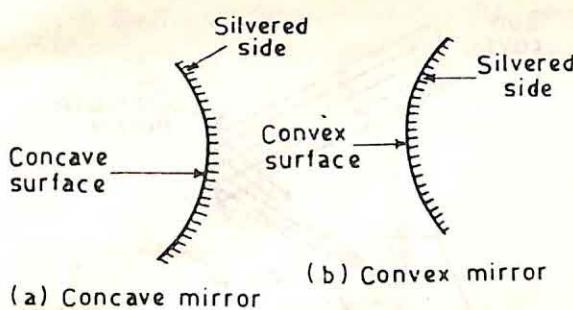
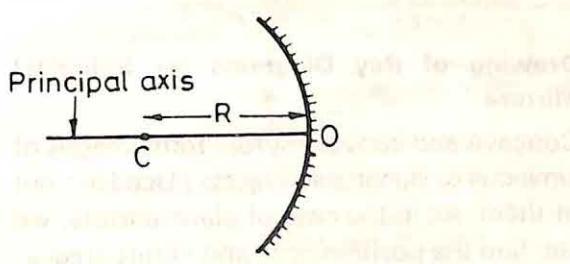
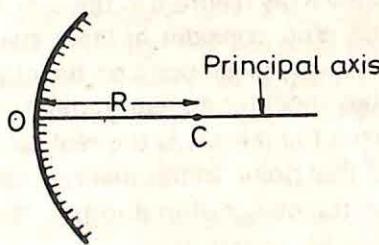


Fig. 5.2

in a spherical mirror, it is necessary to define the terms related to spherical mirrors (see Fig. 5.3).



(a) Concave mirror



(b) Convex mirror

Fig. 5.3

1. *Pole*: The geometric centre of the spherical surface of the mirror is called the *pole* of the mirror. The point marked O is the pole of the mirror.

2. *Centre of Curvature*: The centre of curvature C is the centre of the sphere of which the spherical mirror is a part.

3. *Radius of Curvature*: The radius of curvature R is the radius of the sphere of which the mirror is a part. In Fig. 5.3 one such radius is shown. The distance of any point on the surface of the mirror from the centre of curvature is equal to the radius of curvature. The radius at any point is *normal* to the mirror at that point.

4. *Principal Axis*: The line OC (produced on both sides) joining the pole and the centre of curvature is called the principal axis of the mirror.

#### Focussing Effect of a Spherical Mirror: Focus and Focal Length

What happens when parallel rays fall on a spherical mirror? Figure 5.4 shows parallel rays

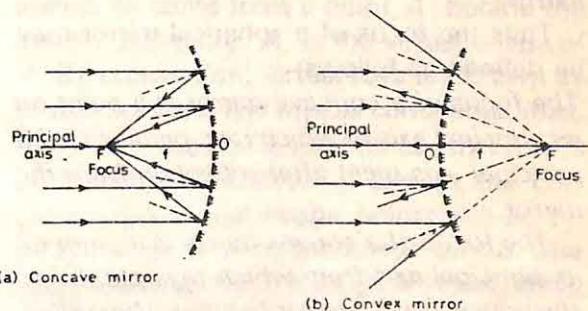


Fig. 5.4

of light falling on a spherical mirror. All the rays are parallel to the principal axis of the mirror. The following argument explains how these rays are reflected by the mirror.

The laws of reflection which hold good for a plane mirror are also obeyed in the case of a spherical mirror. The reason is that a spherical mirror can be regarded as an arrangement of a large number of extremely tiny plane mirrors as shown in Fig. 5.4. Thus, when a ray of light falls on any point, it is reflected from a small plane mirror at that point in such a way that the angle of incidence at that point is equal to the angle of reflec-

tion. The broken lines in front of the mirrors in Fig. 5.4 represent the normals at various points of the mirror. Notice what happens to the reflected rays. They are not parallel. In fact, in the case of a concave mirror shown in Fig. 5.4(a), they meet at a point  $F$  on the principal axis. This point is called the *focus* of the concave mirror. The distance between the pole  $O$  and the focus  $F$  is called the *focal length* ( $f$ ) of the concave mirror.

Now look at the rays reflected from a convex mirror as shown in Fig. 5.4 (b). They are also not parallel. They do not meet at any point. They *appear* to come from a point  $F$  behind the mirror. This point is called the *focus* of the convex mirror. The distance  $OF$  is called the *focal length* ( $f$ ) of the convex mirror.

Thus the focus of a spherical mirror may be defined as follows:

*The focus of a concave mirror is a point on its principal axis at which rays parallel to the principal axis meet after reflection from the mirror.*

*The focus of a convex mirror is a point on its principal axis from which rays parallel to the principal axis appear to come after reflection from the mirror.*

It may be mentioned that *the radius of curvature of a mirror is twice its focal length.*

$$R = 2f$$

### Activity 1

You can easily see the focussing effect of a concave mirror. Borrow a concave mirror from your school physics laboratory and hold it so that it faces the sun as shown in Fig. 5.5. Place a piece of paper in front of it and adjust its distance from the mirror. At one position you will see a very small image of the sun. The rays of the sun (which are parallel) get focussed at this point. Due to focussing of rays, the paper starts burning near this point.

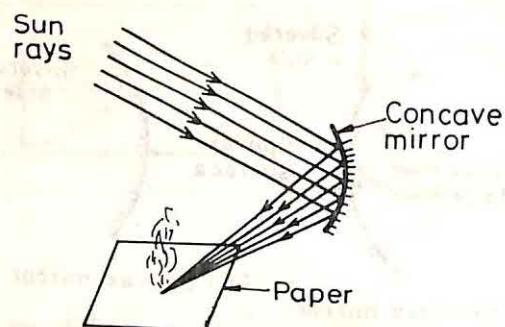


Fig. 5.5

This point is the focus of the mirror. Find the focal length of the mirror.

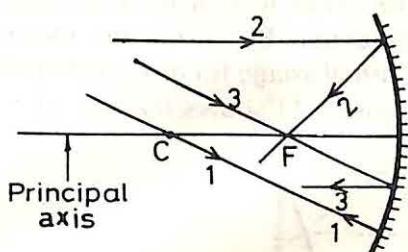
### Drawing of Ray Diagrams for Spherical Mirrors

Concave and convex mirrors form images of luminous or illuminated objects placed in front of them. As in the case of plane mirrors, we can find the position, size and nature (real or virtual) of the image by drawing the ray diagrams. You have already learnt how to draw a ray diagram in the case of a plane mirror. You consider at least *two* rays coming from any given point on the object. Wherever they meet (or appear to meet) after reflection from the mirror, is the real (or virtual) image of that point. In this manner, taking one point on the object after another, the entire image can be constructed.

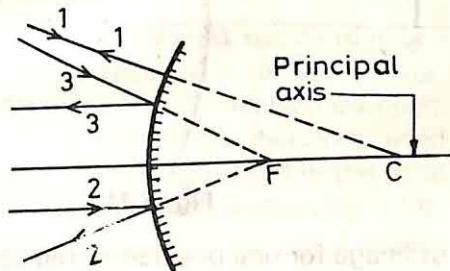
Which two rays are the most convenient to use? You may take any two of the following rays.

1. *Ray Passing through the Centre of Curvature* The normal to a spherical surface at any point is the radius of curvature. Hence the ray passing through the centre of curvature falls normally on the surface; its angle of incidence is zero. Therefore, the angle of reflection is also zero, that is,

the ray is reflected back along the same path. Ray 1 in Figs. 5.6(a) and (b) is one such ray.



(a) Concave mirror



(b) Convex mirror

Fig. 5.6

2. **Ray Parallel to the Principal Axis** The ray parallel to the principal axis will, after reflection, pass through the focus (in the case of a concave mirror) or appear to come from the focus (in the case of a convex mirror). Ray 2 in Figs. 5.6(a) and (b) is one such ray.
3. **Ray Passing through the Focus** The ray passing through the focus (in the case of a concave mirror) or appearing to pass through the focus (in the case of a convex mirror) is reflected parallel to the principal axis. Ray 3 in Figs. 5.6(a) and (b) is one such ray.

#### Images Formed by a Concave Mirror

You can now draw the ray diagrams to find the position, size and nature of the image formed by a concave mirror for different positions of the object placed on the principal axis.

**Case I: Object between  $O$  and  $F$**  Figure 5.7 shows an object  $AB$  placed between pole  $O$

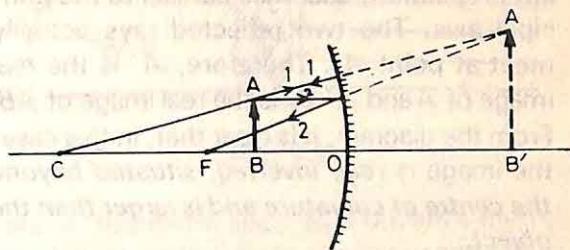


Fig. 5.7

and focus  $F$  of a concave mirror. Two rays marked 1 and 2 from point  $A$  of the object, one parallel to the principal axis and the other passing through the centre of curvature  $C$  are used. After reflection from the mirror, they appear to come from a point  $A'$  behind the mirror. Therefore,  $A'$  is the virtual image of  $A$ . By convention, virtual rays are drawn as broken lines and real rays as continuous lines. If the same method is used for all other points of the object between  $A$  and  $B$ , the corresponding virtual image points still lie on  $A'B'$ . Thus  $A'B'$  is the image of  $AB$ . The diagram shows that the image is *virtual, erect, behind the mirror and larger than the object*.

**Case II: Object between  $F$  and  $C$**  Figure 5.8 shows how the image is formed in this case.

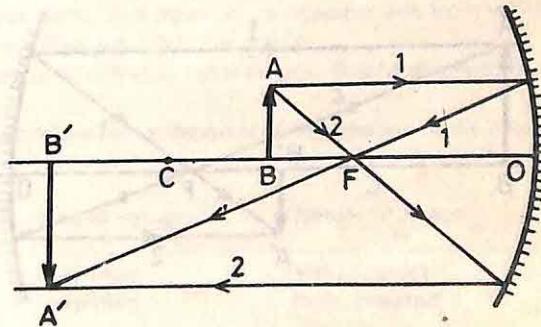


Fig. 5.8

Two rays marked 1 and 2 from point  $A$  of the object are chosen. Ray 1 parallel to the prin-

cipal axis, after reflection, passes through the focus  $F$ . Ray 2, passing through the focus after reflection, becomes parallel to the principal axis. The two reflected rays actually meet at point  $A'$ . Therefore,  $A'$  is the real image of  $A$  and  $A' B'$  is the real image of  $AB$ . From the diagram, it is clear that, in this case, the image is *real, inverted, situated beyond the centre of curvature and is larger than the object*.

**Case III: Object at C** Figure 5.9 shows the

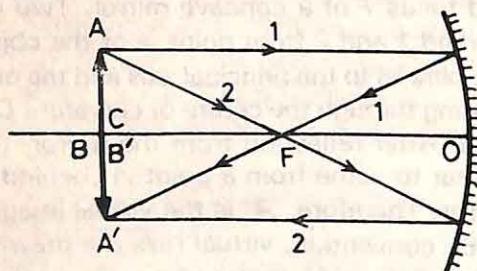


Fig. 5.9

image formation in this case. The image is *real, inverted, situated at the centre of curvature and is of the same size as the object*.

**Case IV: Object beyond C** In this case (see Fig. 5.10) the image is *real, inverted, situated between F and C and is smaller than the object*.

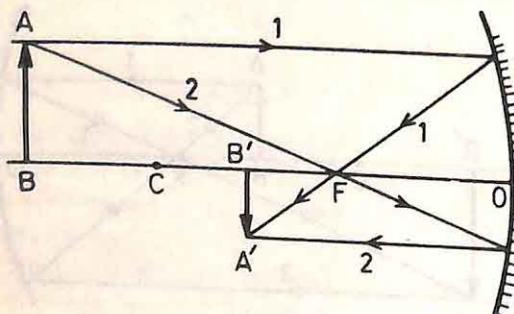


Fig. 5.10

*between F and C and is smaller than the object.*

### Images Formed by a Convex Mirror

The image formed by a concave mirror can be either virtual (when the object is between its pole and focus) or real (when the object is beyond its focus). But a convex mirror forms only a virtual image for any position of the object. Figure 5.11 shows the formation

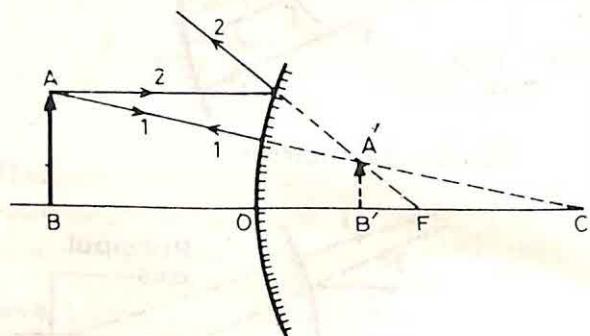


Fig. 5.11

of image for one position of the object. The image is always *virtual, erect, situated behind the mirror between its pole and focus and is always smaller than the object*.

You are advised to draw the ray diagrams for other positions of the object. You will find that the image becomes smaller and moves closer to the focus as the object is moved away from the mirror.

### Uses of Spherical Mirrors

The concave mirror is put to the following uses.

- As a Shaving Mirror** The fact that a concave mirror forms an erect and magnified image of an object placed close to it (see Fig. 5.7) enables us to use it as a shaving mirror (Fig. 5.12).
- As a Doctor's Head Mirror** The fact that a concave mirror focusses a parallel beam of light to a point, enables a doctor to concentrate light on a small area to be examined like teeth, ears, throat, nose, etc.

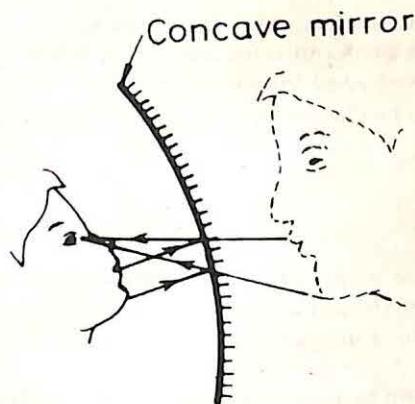


Fig. 5.12

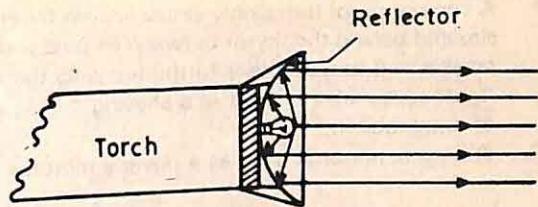


Fig. 5.13

Concave mirror is, therefore, used as a driver's mirror which enables the driver of a car or any other vehicle to have a clear view of the vehicles behind him (Fig. 5.14)

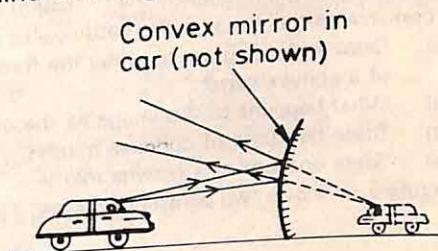


Fig. 5.14

(iii) *As a Reflector* When a source of light is placed at the focus of a concave mirror, a parallel beam of reflected light is obtained. Concave mirrors are therefore, used in torches, search lights and in the head lights of cars and other vehicles (Fig. 5.13).

A convex mirror forms only virtual images for all positions of the object. A convex mir-

### POINTS TO REMEMBER

1. The laws of reflection of light hold for plane as well as curved mirrors.
2. A spherical mirror is a part of a hollow sphere or a spherical surface.
3. The centre of curvature of a spherical mirror is the centre of the sphere of which it is a part. The radius of curvature is the radius of the sphere of which the mirror is a part.
4. The focus of a concave mirror is a point on its principal axis at which rays parallel to the principal axis meet after reflection from the mirror. The focus of a convex mirror is a point on its principal axis from which rays parallel to the principal axis appear to come after reflection from the mirror.
5. The distance between the focus and the pole of a mirror is called its focal length. The focal length of a spherical mirror is equal to half its radius of curvature.
6. The size, location and nature of the image formed by a concave mirror depends on the position of the object as shown in the following table:

Position of Object	Position of Image	Size of Image	Nature of Image
1. Between pole and focus	Behind the mirror	Magnified	Virtual, erect
2. Between focus and centre of curvature	Beyond centre of curvature	Magnified	Real, inverted
3. At centre of curvature	At centre of curvature	Same size	Real, inverted
4. Beyond centre of curvature	Between focus and centre of curvature	Diminished	Real, inverted

- A convex mirror forms only virtual images for any position of the object. The image is always virtual, erect, situated behind the mirror between its pole and focus and is smaller than the object. The image becomes smaller and moves closer to the focus as the object is moved away from the mirror.
- A concave mirror is used as a shaving mirror, as a doctor's head mirror and as a reflector in head lights of automobiles.
- A convex mirror is used as a driver's mirror.

### QUESTIONS

- Explain what is meant by the terms *pole*, *centre of curvature*, *radius of curvature* and *principal axis of a spherical mirror*. Show them on a diagram for a concave mirror and a convex mirror.
- What do you understand by the terms *focus* and *focal length of a spherical mirror*? Show them on a diagram for a concave mirror and a convex mirror.
- By means of ray diagram show how a concave mirror can form (i) a diminished real image, (ii) a magnified real image and (iii) a virtual image of an object placed on its principal axis.
- Draw a ray diagram to show the formation of the image of an object placed at the centre of curvature of a concave mirror. What is the nature, size and position of the image?
- (a) Draw a ray diagram to show the formation of the image of an object placed on the principal axis of a convex mirror.  
(b) What happens to the image as the object is moved away from the mirror?
- (a) State two uses of concave mirrors.  
(b) State one use of a convex mirror.
- Figure 5.15 shows two parallel rays 1 and 2 incident on (a) a concave mirror and (b) a convex mirror. Copy

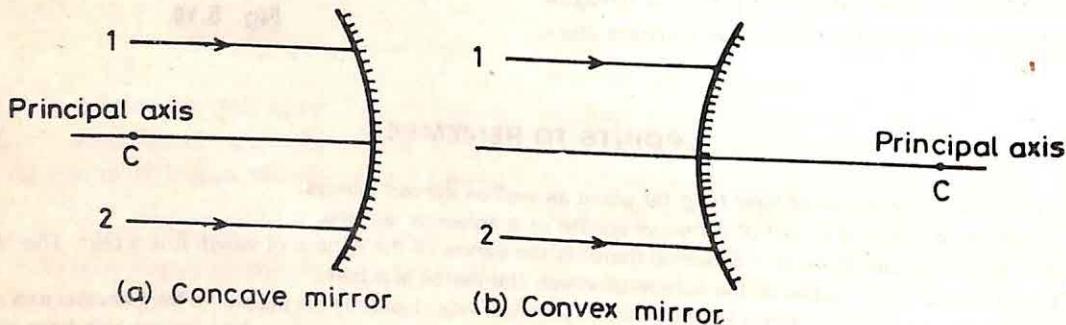


Fig. 5.15

the diagrams in your exercise book. Draw the reflected rays and mark the position of the focus by the letter *F*. *C* is the centre of curvature of the mirror.

- Figure 5.16 shows a concave mirror and a luminous point (tiny) object *P* on its principal axis. *R* is the image

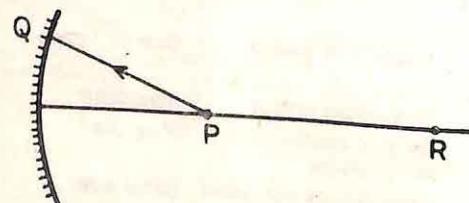


Fig. 5.16

(a) A ray  $PQ$  is incident on the mirror as shown in the diagram. Draw the reflected ray.  
 (b) By construction, locate the point  $C$ , the centre of curvature of the mirror.  
 9. Figure 5.17 shows an object  $AB$  and its image  $A'B'$  formed by a concave mirror. Complete the ray diagram and mark  $F$ , the focus of the mirror.

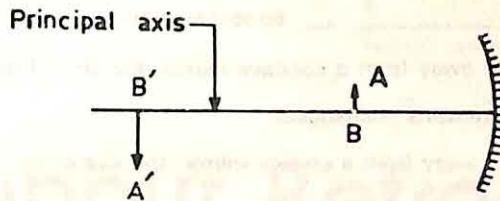


Fig. 5.17

10. Figure 5.18 shows an object  $AB$  and its image  $A'B'$  formed by a convex mirror. Complete the ray diagram and mark  $F$ , the focus of the mirror.

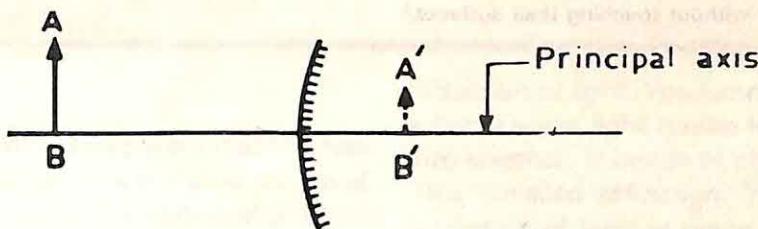


Fig. 5.18

11. Figure 5.19 shows a concave mirror whose centre of curvature is at  $C$ . Mark on the diagram the position

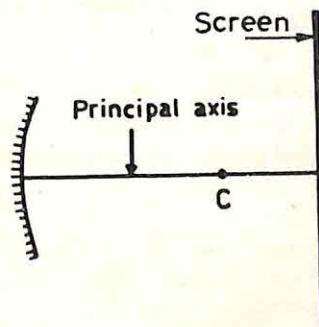


Fig. 5.19

of a point source of light so that a bright circular patch of light of the same size as the mirror is formed on the screen. Draw two rays to show how the patch is formed.

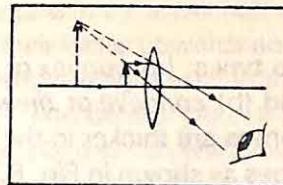
12. *Mark true or false.*

- (i) A convex mirror forms only virtual images.
- (ii) A concave mirror forms only real images.
- (iii) A virtual image cannot be received on a screen.
- (iv) A convex mirror forms a virtual magnified image of an object.
- (v) A driver uses a concave mirror to have a clear view of the traffic behind the car.

13. Fill in the blanks using the choices given in brackets.

- (i) The focal length of a spherical mirror is \_\_\_\_\_ the radius of curvature (equal to, twice, half).
- (ii) A real image \_\_\_\_\_ be received on a screen (can, cannot).
- (iii) As an object is moved away from a concave mirror, the size of its real image \_\_\_\_\_ (decreases, increases, remains unchanged).
- (iv) As an object is moved away from a convex mirror, the size of its image \_\_\_\_\_ (decreases, increases, remains unchanged)
- (v) The reflector used in torch is a \_\_\_\_\_ mirror (concave, convex).
- (vi) A convex surface bulges \_\_\_\_\_ towards the incident light (outwards, inwards).

14. You are given three mirrors; a plane mirror, a convex mirror and a concave mirror. How will you distinguish between them without touching their surfaces?



# More about Refraction of Light

## Lenses

A lens is made of a transparent material having curved surfaces. The surfaces are usually spherical. The lens is a very useful optical device. Lenses are very widely used these days. They are used in various optical devices and instruments such as cameras, picture projectors, telescopes, microscopes, binoculars and spectacles.

The primary function of a lens is to form images of objects. The principle on which a lens works is based on the phenomenon of

refraction of light. You learnt in Class VII that when a ray of light travels from one medium into another, it bends or changes direction. This is called *refraction*. You have studied refraction of light at plane surfaces.

You know that when a ray of light travelling in an optically rarer medium meets the boundary of an optically denser medium, it bends towards the normal as shown in Fig. 6.1(a). But, when a ray of light travelling in an optically denser medium meets the boundary of an optically rarer medium, it bends away from the normal as shown in Fig. 6.1(b).

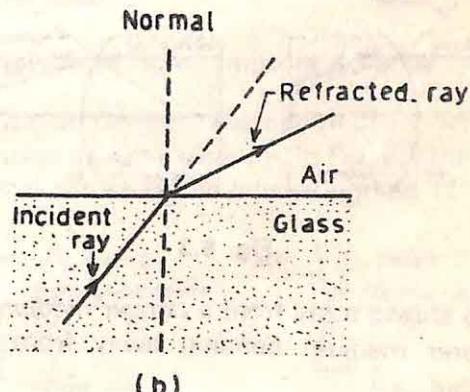
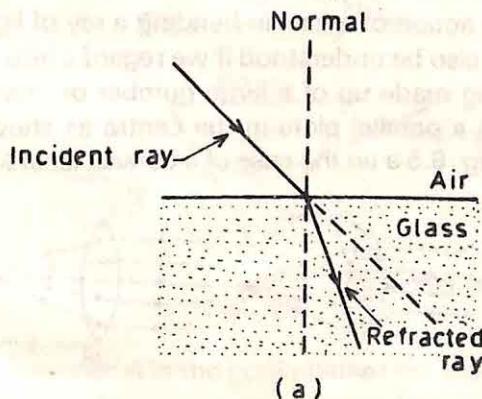


Fig. 6.1

### Types of Lenses

Lenses are of two types: (a) *convex or converging lenses* and (b) *concave or diverging lenses*. Convex lenses are thicker in the centre than at the edges as shown in Fig. 6.2(a).

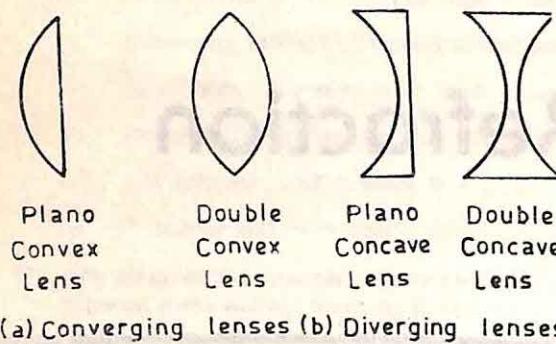


Fig. 6.2

Concave lenses are thinner at the centre than at the edges as shown in Fig. 6.2(b).

### Refraction by a Lens

The laws of refraction for plane surfaces also hold good for spherical surfaces. When a ray of light travelling in an optically rarer medium meets a spherical surface of a denser medium, it bends towards the normal at the point of incidence. This is shown in Fig. 6.3a. Figure

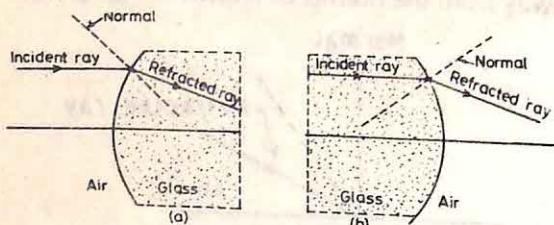
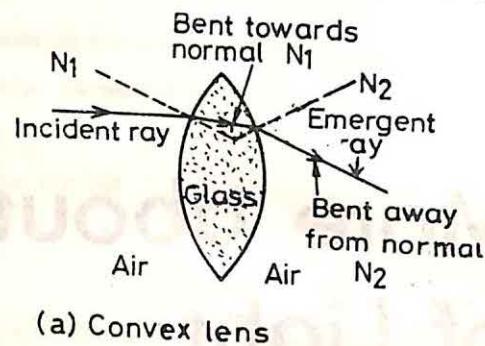


Fig. 6.3

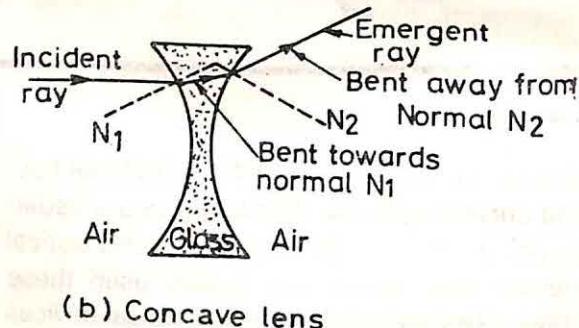
6.3b shows a ray from a denser medium to a rarer medium bending away from the normal.

A lens is formed by a combination of the two surfaces shown in Figs. 6.3a and 6.3b.

One combination gives a convex lens and the other combination gives a concave lens as shown in Figs. 6.4a and 6.4b. These diagrams



(a) Convex lens



(b) Concave lens

Fig. 6.4

also show how a ray of light is bent after suffering refractions at the two faces of the lens.

### Lens as a Combination of Prisms

The action of a lens in bending a ray of light can also be understood if we regard a lens as being made up of a large number of prisms with a parallel plate in the centre as shown in Fig. 6.5 a (in the case of a convex lens) and

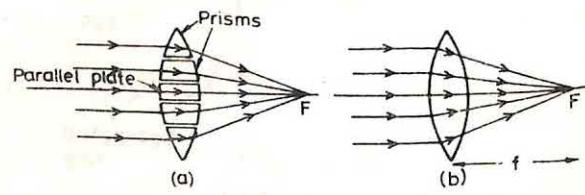


Fig. 6.5

Fig. 6.6(a) ( in the case of a concave lens). You have learnt last year that a prism bends

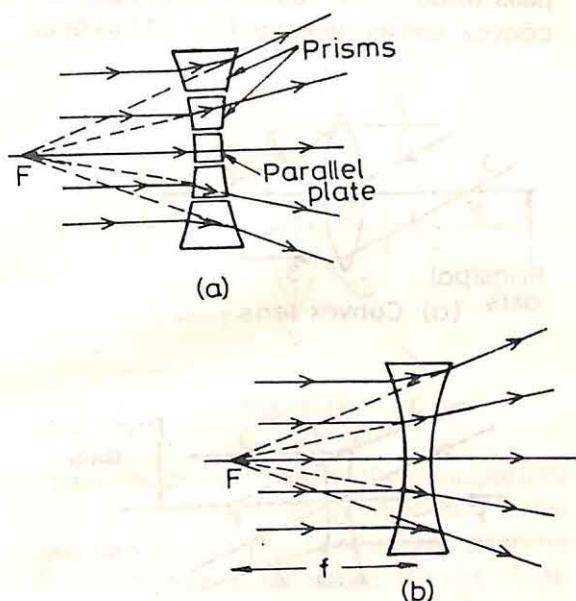


Fig. 6.6

a ray of light towards its base as shown in Fig. 6.7.

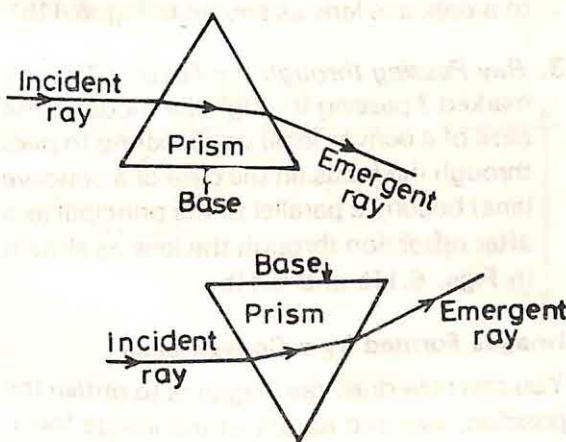


Fig. 6.7

The prisms in the upper half of the convex lens have their bases downwards (Fig. 6.5a). These prisms will bend the rays downwards

The prisms in the lower half of the convex lens have their bases upwards and, therefore, they will bend the light upwards as shown in Fig. 6.5(a). The central part of the lens is just a parallel plate which will allow the incident ray to pass unbent as shown in Fig. 6.8. Also, the

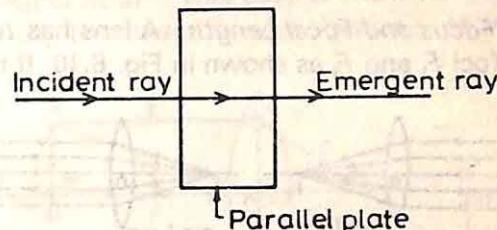


Fig. 6.8

farther the prism from the centre of the lens, the greater is the bending of rays. The rays emerging from the prisms meet a point *F* which is called the *focus* of the lens. Figure 6.5(b) shows the bending of parallel rays by the convex lens as a whole. The rays converge to a point *F*. That is why a convex lens is called a converging lens.

The bending of parallel rays by a concave lens is shown in Figs. 6.6(a) and 6.6(b). The parallel rays become *divergent* after refraction through the lens. That is why a concave lens is called a diverging lens. The diverging rays appear to come from a point *F* called the focus of the lens.

#### Definition of Some Important Terms

1. *Optical Centre* The centre of the lens is called its *optical centre*. In Fig. 6.9 the optical centre of the lens is marked *O*.

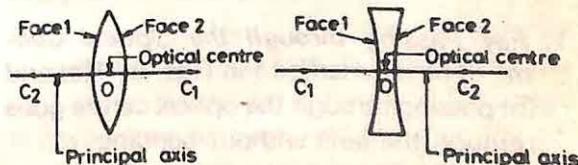


Fig. 6.9

**2. Principal Axis** The line joining the centres of curvature of the two faces of the lens is called its *principal axis*. It passes through the optical centre (Fig. 6.9).  $C_1$  is the centre of curvature of face 1 and  $C_2$  that of face 2.

**3. Focus and Focal Length** A lens has two foci  $F_1$  and  $F_2$  as shown in Fig. 6.10. If the

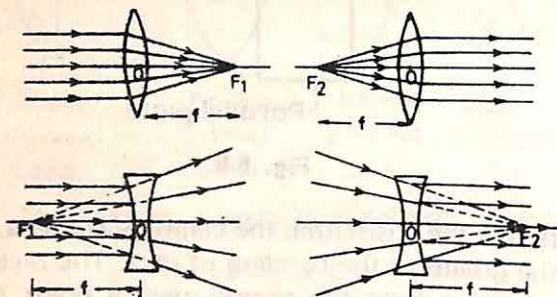


Fig. 6.10

two faces of the lens have the same radius of curvature (as in the case of a double-convex or double-concave lens), the two focus points  $F_1$  and  $F_2$  are at the same distance from the optical centre. This distance is called the *focal length* ( $f$ ) of the lens.

#### Drawing of Ray Diagrams for Lenses

Convex and concave lenses form images of objects. We can determine the position, size and nature (real or virtual, inverted or erect) of the image by drawing the ray diagrams. To draw a ray diagram, you may take any two of the following three most convenient rays coming from any point on an object.

- 1. Ray Passing through the Optical Centre** The ray marked 1 in Figs. 6.11(a) and (b) passing through the optical centre goes through the lens without bending.
- 2. Ray Parallel to the Principal Axis** The ray

marked 2 which is parallel to the principal axis will, after refraction through the lens, pass through the focus (in the case of a convex lens as shown in Fig. 6.11 a) or ap-

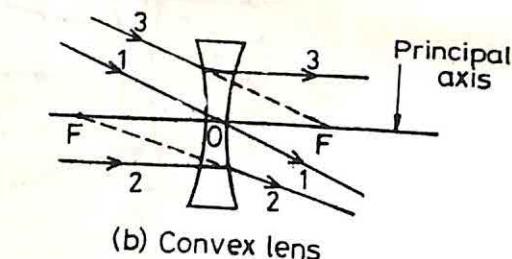
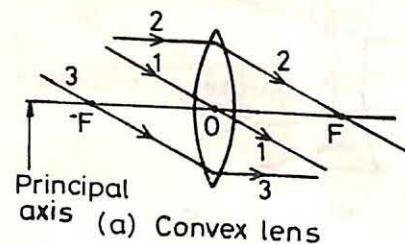


Fig. 6.11

pear to pass through the focus (in the case of a concave lens as shown in Fig. 6.11b).

- 3. Ray Passing through the Focus** The ray marked 3 passing through the focus (in the case of a convex lens) or appearing to pass through the focus (in the case of a concave lens) becomes parallel to the principal axis after refraction through the lens as shown in Figs. 6.11a and 6.11b.

#### Images Formed by a Convex Lens

You can now draw ray diagrams to obtain the position, size and nature of the image formed by a convex lens for various positions of the object on the principal axis.

- 1. Object between O and F** An object  $AB$  is placed on the principal axis of the lens between the optical centre  $O$  and focus  $F$ .

of the lens as shown in Fig. 6.12. Two rays, one passing through the optical centre (ray

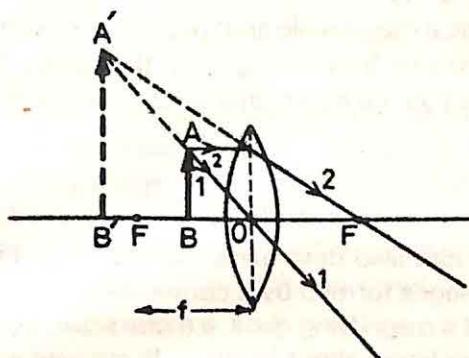


Fig. 6.12

1) and the other parallel to the principal axis (ray 2) are taken. After refraction, these two rays are divergent and appear to come from  $A'$  which is, therefore, the virtual image of  $A$ . Similarly  $B'$  is the virtual image of  $B$ . Hence  $A'B'$  is the virtual image of  $AB$ . This image is *erect, virtual, magnified and on the same side of the lens as the object*.

**2. Object between  $F$  and  $2F$**  Figure 6.13

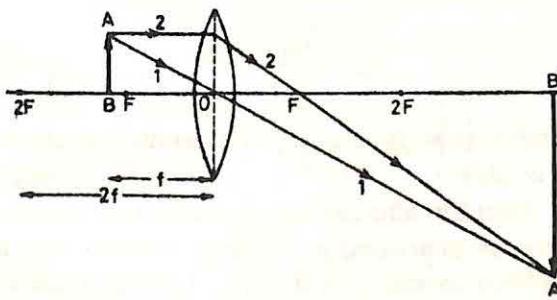


Fig. 6.13

shows an object  $AB$  placed between the focus  $F$  and a point marked  $2F$ . The point marked  $2F$  is at a distance of  $2f$  from the lens, where  $f = OF$  is the focal length of the lens. The two refracted rays 1 and 2 actually meet at  $A'$  in this case. Therefore,

$A'$  is the real image of  $A$ . Thus  $A'B'$  is the real image of  $AB$ . Thus, in this case, the image is *real, inverted, magnified and located beyond  $2F$  on the other side of the lens*.

**3. Object at  $2F$**  This case is shown in Fig. 6.14. The image is *real, inverted, of the*

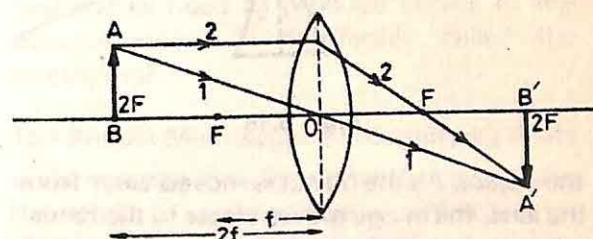


Fig. 6.14

*same size as the object and is located at a distance of  $2f$  from the lens*.

**4. Object beyond  $2F$**  Figure 6.15 shows the

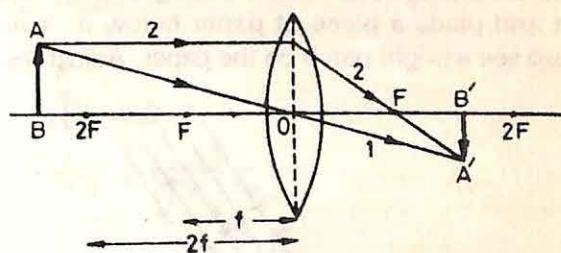


Fig. 6.15

formation of image in this case. The image is *real, inverted, diminished and lies between  $F$  and  $2F$* .

#### Images Formed by a Concave Lens

A concave lens forms only virtual images for all positions of the object. Figure 6.16 shows how the virtual image is formed. The image is *always virtual, erect, smaller than the object and lies between the optical centre  $O$  and the focus  $F$  of the lens on the same side as*

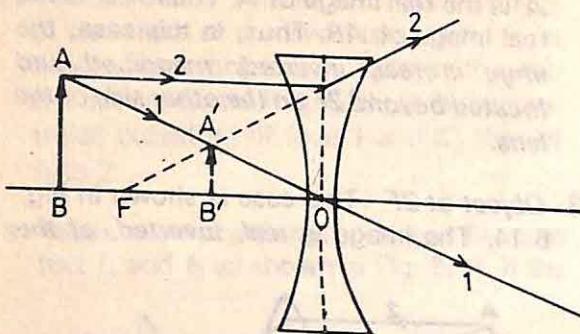


Fig. 6.16

the object. As the object is moved away from the lens, the image moves closer to the focus.

### Activity 1

You can see the focussing action of a convex lens. Take a magnifying glass; this is a convex lens fixed in a frame with a handle and is available in stationery shops, it is also called a reading lens. Allow sunlight to fall on it and place a piece of paper below it. You will see a bright patch on the paper. Adjust the

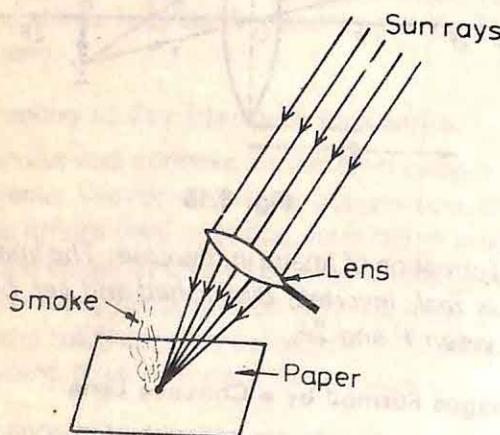


Fig. 6.17

distance of the lens from the paper until the spot of light is really small and bright. The rays from a far off object like the sun are practically

parallel. The lens focusses the rays to a spot. The paper near this spot will begin to smoke (Fig. 6.17).

Use a metre scale and measure the distance of the lens from the spot on the paper. This gives you the approximate focal length of the lens.

### Activity 2

You can also determine the nature and size of images formed by a convex lens. You will need a magnifying glass, a metre scale, a piece of cardboard about  $10\text{ cm} \times 15\text{ cm}$  with white paper pasted on one side, a candle and some plasticine. The white side of the card will serve as a screen to receive the image.

With the help of plasticine, fix the lens and the screen on the metre scale as shown in Fig. 6.18. Make sure that the lens and the screen

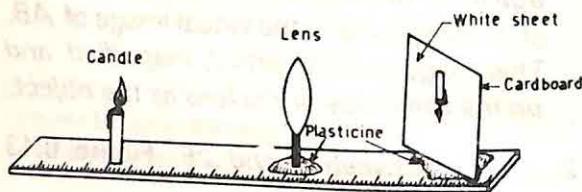


Fig. 6.18

are vertical. A small lighted candle will act as the object.

Find the approximate focal length  $f$  of the lens as described in Activity 1 above. Fix a lighted candle at a distance greater than  $2f$  from the lens. Move the screen backwards and forwards until you see a clear inverted image of the candle on the screen. Is the image smaller or bigger than the object?

Now place the candle at a distance of  $2f$  from the lens. Move the screen to obtain a clear image of the candle. Is the image of the same size as the object?

Move the candle closer to the lens so that

it is between  $f$  and  $2f$  from the lens. Adjust the position of the screen. Do you now see a magnified, inverted image of the candle?

All these images are real. You have received them on your screen.

Finally move the candle very close to the lens so that it lies inside the focus. Can you obtain any image on the screen? *You will only be able to see the magnified and erect image if you look through the lens.* This image is virtual and hence it cannot be received on the screen.

## Optical Instruments

Lenses are used in many optical instruments. We shall study some of the simplest of these instruments.

### The Camera

A photographic camera consists of a convex lens fitted in one face of a light-proof box which is painted black on the inside. A strip of photographic film is placed at the other face of the box as shown in Fig. 6.19. The lens

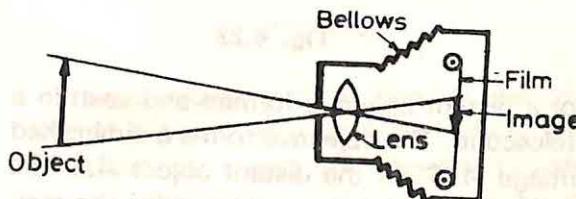


Fig. 6.19

forms a real, inverted and diminished image on the film.

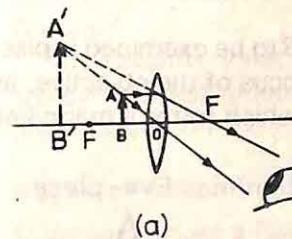
You know that the distance of the image from the lens depends upon the distance between the object and the lens. Thus, when the distant objects are *in focus* (that is, their image is formed on the film), the nearby objects will be *out of focus*. To enable distant and nearby objects to be photographed by the

same camera, a bellow is used so that the distance between the lens and the film can be altered at will. This motion of the lens so as to obtain the image on the film is called *focussing*.

After exposure, the film is treated with chemicals and a permanent image appears on the film. This is called the *negative*. The negative is used to produce copies of the positive which is commonly called the *photograph*.

### The Simple Microscope or Magnifying Glass

A microscope is an instrument for examining the details of very tiny objects which are not clearly visible to the naked eye. A simple microscope or magnifying glass is just a convex lens. The small object to be examined is placed between the optical centre and the focus of the lens and the eye is placed just behind the lens. A magnified, erect and virtual image is formed by the lens as shown in Fig. 6.20a.



(a)

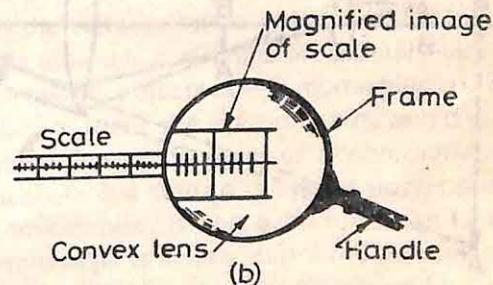


Fig. 6.20

A magnifying glass is a convex lens fixed in a circular frame with a handle as shown in Fig. 6.20b. In a laboratory, it is used to read scales where divisions are marked very close to each other. It can be used to examine fingerprints or tiny insects. *The shorter the focal length of the lens, the greater is the magnification of the image of an object.*

### The Compound Microscope

With a simple magnifying glass, a magnification of about 10 be achieved. A magnification of 10 means that the image is 10 times larger than the object. When higher magnification is desired, a *compound microscope* is used. It was invented by Galileo in 1610.

A compound microscope consists of two convex lenses called the *objective* (or the object lens) and the *eye-piece* (called the eye lens). The objective is a convex lens of very short focal length and is placed close to the object. The eye-piece is a convex lens of a slightly longer focal length and is placed close to the eye.

The tiny object  $AB$  to be examined is placed just beyond the focus of the objective, as shown in Fig. 6.21, which forms a magnified

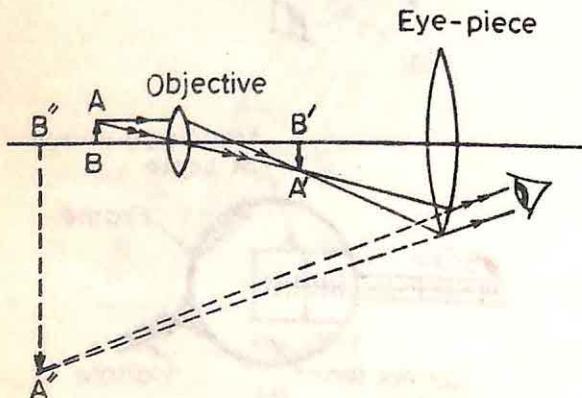


Fig. 6.21

image  $A'B'$ . The image  $A'B'$  acts as an object for the eye-piece which forms the final highly magnified image  $A''B''$ . This final image is seen by the eye.

A magnification of about 1000 can be achieved with a compound microscope.

### The Telescope

A telescope is an instrument which is used to see distant object such as the moon, stars and distant objects on earth. It was invented by Johannes Kepler in 1611. It consists of two convex lenses—an *objective of long focal length* and an *eye-piece of extremely short-focal length*.

Figure 6.22 shows how a magnified image

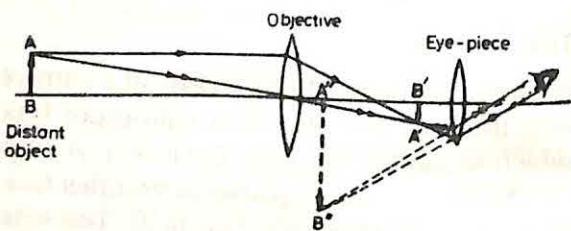


Fig. 6.22

of a distant object is formed and seen in a telescope. The objective forms a diminished image  $A'B'$  of the distant object  $AB$ . The image  $A'B'$  acts as an object for the eye-piece. The eye-piece simply acts as a magnifying glass and forms the final image  $A''B''$  which is seen by the eye. This image is virtual, inverted and highly magnified.

Telescopes are used to study the surface features of the moon and planets and to study their motion. Astronomers have discovered many new things with the help of telescopes—craters on the moon, the rings of saturn, the satellites of Jupiter, etc.

### Activity 3: Making a Telescope

Take two metal or cardboard tubes, one of a slightly smaller diameter than the other so that one can slide into the other. If you cannot find such tubes you can make them with chart paper and gum. Blacken the inside of the tubes.

From your school physics laboratory borrow two convex lenses of focal lengths about 5 cm and 25 cm each. With some plasticine, fix the lens of focal length 25 cm at one end of the bigger tube. This lens is the objective of your telescope and will be directed towards the object to be seen. Fix the lens of focal length 5 cm at the end of the smaller tube. This lens is the eye-piece as the eye will be placed near it (Fig. 6.23).

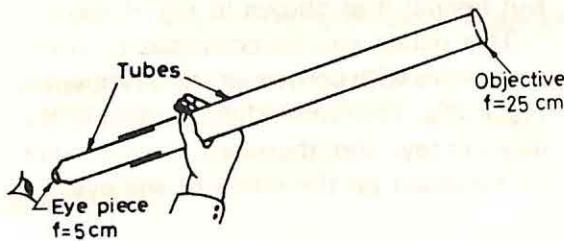


Fig. 6.23

Your telescope is ready. Use it to see a distant object such as a small bird sitting on a tree. Does the object look bigger and closer? Can you now examine the details of the object? The magnifying power of the telescope can be increased if the objective of a longer focal length and eyepiece of a shorter focal length are used.

### The Human Eye

The human eye is a remarkable optical instrument. It is like a camera having a lens on one side and a sensitive screen called the *retina* on the other. The essential parts of a human

eye are shown in Fig. 6.24.

In front of the eye is a transparent film call

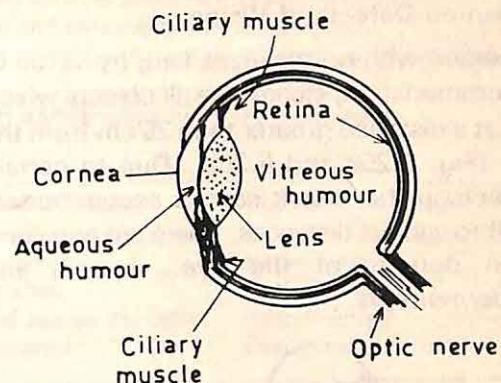


Fig. 6.24

ed *cornea* which bulges outward. Behind the cornea is the crystalline lens which is held in position by a pair of *ciliary muscles*. The space between the cornea and the lens is filled with a watery fluid called the *aqueous humour*. The space between the lens and the retina is filled with a transparent fluid called the *vitreous humour*.

The sensitive inner surface at the back of the eye is called *retina*. The images of objects are received on the retina.

### Power of Accommodation

Hold your finger a few centimetres from the eye and focus on it. You can see your finger but the distant objects become blurred. Now relax your eye and focus on a distant object. The nearby objects now become blurred. The ability to focus the eye on nearby and distant objects is called *power of accommodation*. But there is a limit to the eye's power of accommodation. It can accommodate to see distant objects clearly, but if the object is too close to the eye, it is not clearly visible. The smallest object distance at which clear vision is obtained by accommodation is about 25 cm

for a normal eye. This distance is called the *shortest distance of distinct vision*.

### Common Defects of Vision

A person with normal eyes can, by virtue of accommodation, clearly see all objects which are at a distance greater than 25 cm from the eye (Fig. 6.25a and 6.26a). Due to certain defects in the eye, it cannot accommodate itself to various distances. There are two common defects of the eye: *myopia* and *hypermetropia*.

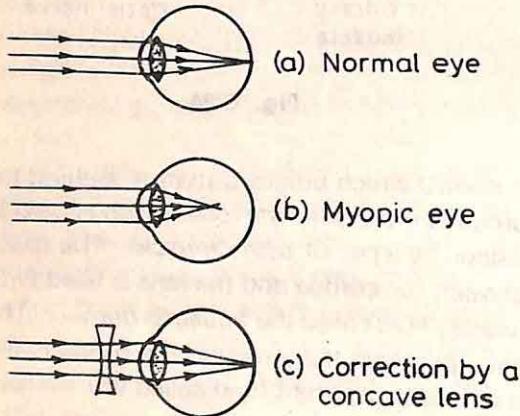


Fig. 6.25

1. *Myopia (or shortsightedness)* A person suffering from myopia (or shortsightedness) cannot clearly see distant objects but can easily see objects nearby. The reason is that the image of a distant object is not formed at the retina but in front of it as shown in Fig. 6.25b.

This defect can be corrected by using spectacles having concave lenses as shown in Fig. 6.25c. The concave lens diverges the incident rays and, therefore, they can now be focussed on the retina of the eye.

2. *Hypermetropia (or Longsightedness)* A person suffering from hypermetropia (or longsightedness) can see distant objects clearly, but objects nearby will seem blurred. The reason is that the image of a nearby object is not formed on the retina but behind it as shown in Fig. 6.26b.

This defect can be corrected by using spectacles with convex lenses as shown in Fig. 6.26c. The convex lens converges the incident rays and, therefore, they can now be focussed on the retina of the eye.

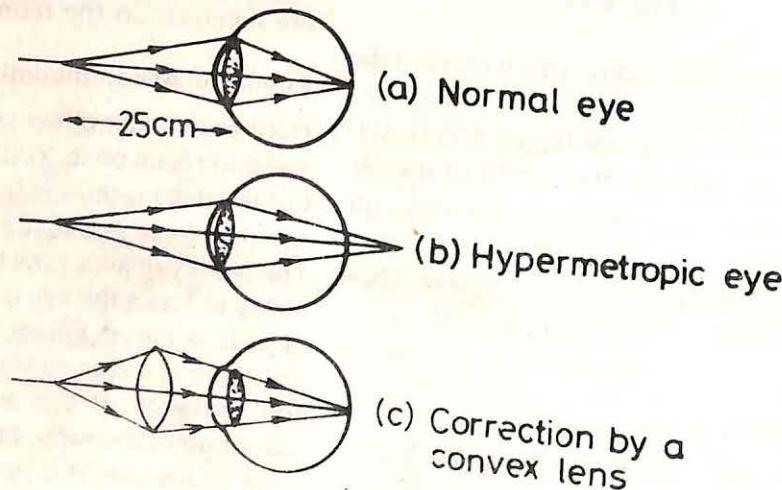


Fig. 6.26

## POINTS TO REMEMBER

1. A lens is made of a transparent material having curved surfaces which are usually spherical.
2. Lenses are of two types: convex or converging lenses and concave or diverging lenses.
3. A convex lens can form virtual or real image depending on the position of the object as summarized in the following table.

$O$  = optical centre,  $F$  = focus of lens,  $2F$  = point at a distance of twice the focal length

Position of the object	Position of the image	Size of the image	Nature of the image
1) Between $O$ and $F$	Behind the object	Magnified	Virtual, erect
2) Between $F$ and $2F$	Beyond $2F$	Magnified	Real, inverted
3) At $2F$	At $2F$	Same size as the object	Real, inverted
4) Beyond $2F$	Between $F$ and $2F$	Diminished	Real, inverted

4. A concave lens forms only virtual images for all positions of the object. The image is always virtual, erect, smaller than the object and lies between the optical centre and the focus on the same side of the lens as the object. As the object is moved away from the lens, the image moves closer to the focus.
5. Lenses are used in many optical instruments such as cameras, telescopes, microscopes, spectacles, etc.
6. There are two common defects of the human eye: myopia (or shortsightedness) and hypermetropia (or longsightedness).
7. A person suffering from myopia cannot clearly see distant objects. This defect is corrected by using spectacles with concave lenses.
8. A person suffering from hypermetropia cannot clearly see nearby objects. This defect is corrected by using spectacles with convex lenses.

## QUESTIONS

1. What is a lens? Name the two types of lenses.
2. Draw neat diagrams to show the converging action of a convex lens and the diverging action of a concave lens.
3. What do you understand by the terms 'focus' and 'focal length' of (i) a convex lens and (ii) a concave lens. Draw ray diagrams and mark focus and focal length.
4. Draw a ray diagram to show how a convex lens forms a virtual magnified image of an object.
5. Draw ray diagrams to show how a converging lens forms (i) a real diminished image of an object, and (ii) a real magnified image of an object.
6. Where should an object be placed in front of a convex lens so as to obtain its real image of the same size as the object? Illustrate by drawing a neat ray diagram.
7. (a) Draw a ray diagram to show how a concave lens forms the image of the object.  
(b) What is the position, nature and size of the image in relation to that of the object?  
(c) What happens to the image if the object is moved away from the lens?
8. Describe a simple photographic camera and explain how it works. Draw a labelled diagram.
9. (a) What is the function of a microscope?  
(b) Draw a ray diagram to illustrate the action of a simple magnifying glass.
10. (a) What is a compound microscope?  
(b) Draw a ray diagram to illustrate the formation of the final image in a compound microscope.
11. (a) What is the function of a telescope?  
(b) Draw a ray diagram showing the formation of the image of a distant object as seen through a telescope.
12. (a) Draw a labelled diagram showing the essential parts of a human eye.  
(b) What is meant by the power of accommodation of an eye?

13. (a) Explain what is meant by shortsightedness and longsightedness of an eye.  
 (b) Draw neat diagrams to show how each defect is corrected.  
 14. What is the difference between a telescope and a microscope?  
 15. How will you distinguish between a convex lens, a concave lens and a thin glass plate without touching them?  
 16. Complete the ray diagrams in Fig. 6.27.

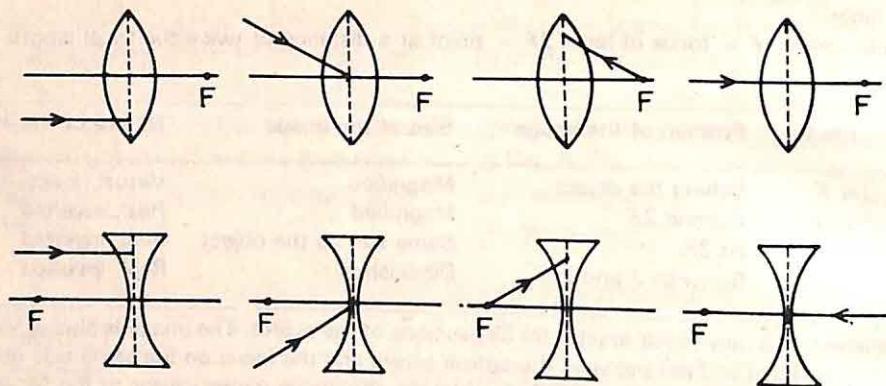


Fig. 6.27

17. Complete the ray diagrams shown in Fig. 6.28 and find out the nature of the image in each case.

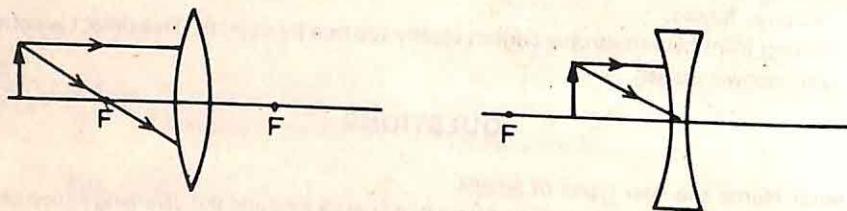


Fig. 6.28

18. Match items in column I with those in column II

Column I	Column II
1. Microscope	(i) Instrument to view distant objects.
2. Hypermetropia	(ii) Bending of a ray of light when it travels from one medium into another.
3. Refraction	(iii) A point on the principal axis where rays parallel to the principal axis converge after refraction through a convex lens.
4. Telescope	(iv) Instrument to look at details of tiny objects.
5. Focus	(v) Ability of the eye to focus on nearby and distant objects.
6. Accommodation	(vi) is corrected by using a convex lens in the spectacles.

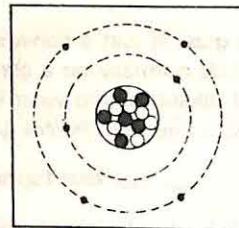
19. Mark true or false

(i) A convex lens, if suitably placed in front of an object, can form its virtual image.  
 (ii) A concave lens, if suitably placed in front of an object, can form its real image.  
 (iii) A photographic camera will work if its convex lens is replaced by a concave lens of the same focal length.

(iv) A magnifying glass is just a convex lens.  
(v) A ray which falls normally on a glass slab does not suffer refraction.  
(vi) A longsighted person has to wear spectacles to see distant objects.

20. *Filling in the blanks using the choices given in the brackets.*

- A \_\_\_\_\_ lens forms real as well as virtual images. (convex, concave).
- The nearest distance of distinct vision for a normal human eye is \_\_\_\_\_ cm.  
(zero, 25, 50, infinite)
- A person reading a book by holding it at an arm's length suffers from a defect called \_\_\_\_\_.  
(shortsightedness, longsightedness)
- Shortsightedness can be remedied by using a \_\_\_\_\_ lens. (convex, concave).
- A \_\_\_\_\_ image cannot be received on a screen. (real, virtual)
- The magnifying power of a telescope increases if the focal length of the \_\_\_\_\_ is increased while that of \_\_\_\_\_ is decreased (objective, eye-piece).



# Static Electricity

The word electricity comes from a Greek word *elektron* which means *amber*. Amber is a kind of resin. About 2500 years ago, a Greek philosopher Thales found that when a piece of amber was rubbed with fur, it would attract small pieces of leaves, cork, or even dust. Today we know that many other materials, such as plastic, nylon, glass, hard rubber, sealing wax and ebonite show the same effect. A substance which shows this effect is said to be *electrified* or *charged*.

### Activity 1

Place some tiny bits of paper on a table. Hold a plastic ruler or plastic pen close to the bits of paper. The plastic ruler or pen does not attract them. Now rub the ruler or pen with dry hair or a piece of wool and bring it near the bits of paper. What do you observe? The pieces of paper will jump up and stick to the pen or ruler as shown in Fig. 7.1.

Try a second experiment. Inflate a rubber

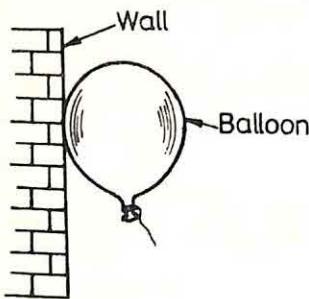
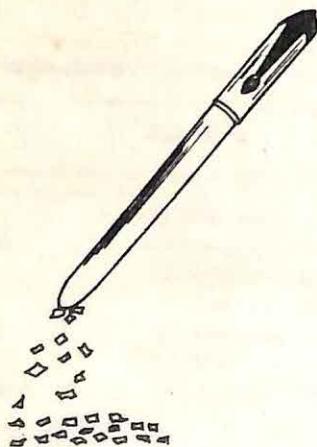


Fig. 7.1

ballon. Rub it against a woollen material and place it against a wall. What do you find? You will find that it sticks to the wall (Fig. 7.1).

You must have experienced this attraction while combing your hair or taking off a shirt made of synthetic fibre. In each case the object is *charged* by the rubbing process and it is said to possess an *electric charge* or *static electricity*.

### Two kinds of Electric Charge

You have seen that an object can be charged by rubbing. A glass rod rubbed with silk attracts pieces of paper. Similarly an ebonite rod rubbed with fur will also attract pieces of paper. Both glass and ebonite are charged by rubbing.

The first step in the development of the science of electricity was taken when scientists found that two glass rods rubbed with silk *repel* each other. Similarly two ebonite rods rubbed with fur also *repel* each other. But a glass rod rubbed with silk and an ebonite rod rubbed with fur *attract* each other. These can be demonstrated by the following experiment.

A glass rod rubbed with silk is suspended from a thread and another glass rod rubbed

with silk is brought near it as shown in Fig. 7.2a. The two rods repel each other. Similarly, two ebonite rods rubbed with fur repel each other (Fig. 7.2 b). In the third experiment, a glass rod rubbed with silk is suspended by a piece of thread and an ebonite rod rubbed with fur is brought near it as shown in Fig. 7.2c. It is found that the two rods attract each other.

If the rods are not rubbed with silk or fur, no attraction or repulsion is observed. Thus we concluded that the force of attraction or repulsion arises because the rods are charged. Such forces are called electrostatic forces.

### Activity 2

You will need two small balloons, a woollen pullover or garment and some cotton thread. Inflate the balloons and tie them up with a length of cotton thread. Rub the balloons against woollen material. Hold the free ends of the threads in your hands and drop the balloons (Fig. 7.3). You will find that the balloons repel each other.

The observations of the experiments shown in Fig. 7.2 clearly suggest that the charge developed on the glass rod when rubbed with

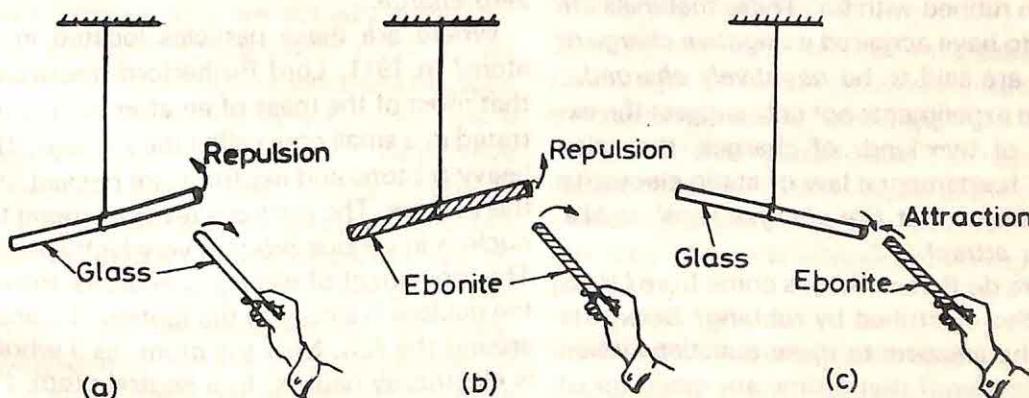


Fig. 7.2

silk must be opposite to the charge developed on the ebonite rod when rubbed with fur. When other materials that can be charged by rubbing are tested in a similar fashion, it is found that they fall into the following two categories:

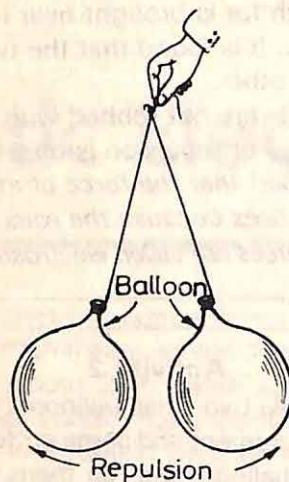


Fig. 7.3

1. Some materials develop the same kind of charge as that developed on a glass rod when rubbed with silk. Such materials are said to have acquired a *positive charge* or they are said to be *positively charged*.
2. Other materials develop the same kind of charge as that developed on an ebonite rod when rubbed with fur. These materials are said to have acquired a *negative charge* or they are said to be *negatively charged*.

These experiments not only suggest the existence of two kinds of charges, they also verify a fundamental law of static electricity which states that *like charges repel, unlike charges attract*.

Where do these charges come from? How are bodies electrified by rubbing? Scientists found the answers to these questions when they discovered that atoms are made up of smaller particles called *electrons*, *protons* and *neutrons*.

### Structure of Atom: What are Atoms made of?

You know that matter is composed of tiny particles called molecules. Many of these molecules are made up of similar or different particles called atoms. For quite some time scientists believed that atoms were the smallest building units of all substances and that an atom could not be further divided.

In the first half of the twentieth century, scientists discovered that the atom is composed of smaller particles, some negatively charged, some positively charged and some without any charge. The *negatively charged* particles are called *electrons*, the *positively charged* particles are called *protons* the *uncharged* particles *neutrons*.

Experimental observations showed that the mass of a proton is almost equal to that of a neutron, but electron has a very little mass. The mass of an electron is about  $1/1840$  of that of a proton.

Scientists discovered that the amount of negative charge on an electron is equal to the amount of positive charge on a proton. Scientists consider *each electron as one unit of negative electricity or charge*, that is, *an electron carries a unit negative charge*. *A proton carries a unit positive charge*. *A neutron has zero charge*.

Where are these particles located in an atom? In 1911, Lord Rutherford discovered that most of the mass of an atom is concentrated in a small core called the *nucleus*. The heavy protons and neutrons are packed into this nucleus. The electrons revolve around the nucleus in various *orbits* at very high speeds. The movement of electrons in orbits around the nucleus is similar to the motion of planets around the sun. Now the atom, as a whole, is electrically neutral. In a neutral atom, the number of electrons is equal to the number of protons. Thus, if an atom has one proton,

it will have just one electron revolving around its nucleus, and if an atom has eight protons, it will have eight electrons.

The atoms of different elements have a different number of protons and neutrons in the nucleus. For example, an atom of hydrogen has only one proton and no neutron, an atom of helium has two protons and two neutrons and an atom of aluminium has 13 protons and 14 neutrons in its nucleus. Figure 7.4 shows a model of an atom of carbon which has 6

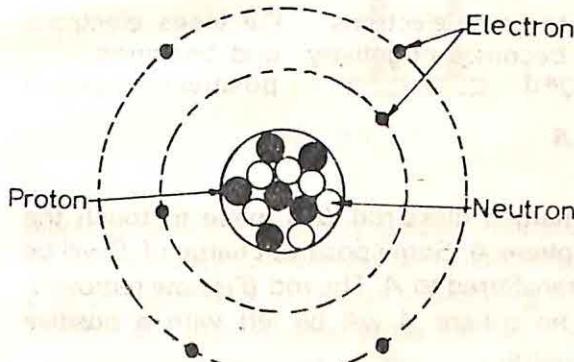


Fig. 7.4

protons and 6 neutrons in its nucleus with 6 electrons revolving around it in two orbits. In this simple model, the orbits of electrons are shown circular, they are actually *elliptical*.

The electrons in the orbits close to the nucleus are called *bound electrons* because they are tightly bound to the nucleus by a strong attractive force between the positive charge of the nucleus and the negative charge of the electrons. But the electrons in orbits far away from the nucleus experience very little force of attraction and so are called *free electrons*. The free electrons can, therefore, be transferred from one body to another. If this happens the atom is left with an extra number of protons. It becomes *positively charged*. The other body which gains an ex-

tra number of electrons becomes *negatively charged*.

*Atoms having a charge on them are called ions. Atoms which have a shortage or deficit of electrons are called positive ions; they have a positive charge. Atoms which have extra or surplus electrons are called negative ions; they have a negative charge.*

### Explanation of Charging by Rubbing

The free electrons in the atoms of some substances such as glass are held less tightly to their nuclei than those in the atoms of other substances such as silk. Thus when a glass rod is rubbed with silk, some electrons are transferred from glass to silk. The glass rod loses some electrons and the silk gains them. Thus, the glass rod develops a positive charge (due to a deficit of electrons) and the silk develops an equal negative charge (due to a surplus of electrons). This is shown in Fig. 7.5a. Similarly, the electrons in ebonite are more tightly bound than those in fur. Therefore, if an ebonite rod is rubbed with fur, electrons are transferred from fur to ebonite. Hence, the ebonite develops a negative charge and fur an equal and opposite positive charge. This is shown in Fig. 7.5b.

### Conservation of Charge

The total number of electrons in glass and silk taken together always remains the same. Due to rubbing, some electrons are simply transferred from glass to silk. The number of electrons lost by glass is equal to the number of electrons gained by silk. In other words, the *total charge is always conserved in any process*.

### Conductors and Insulators

You already know that substances such as silver, copper, aluminium, iron, mercury, coal, acids, alkalis, salts, earth and the human body

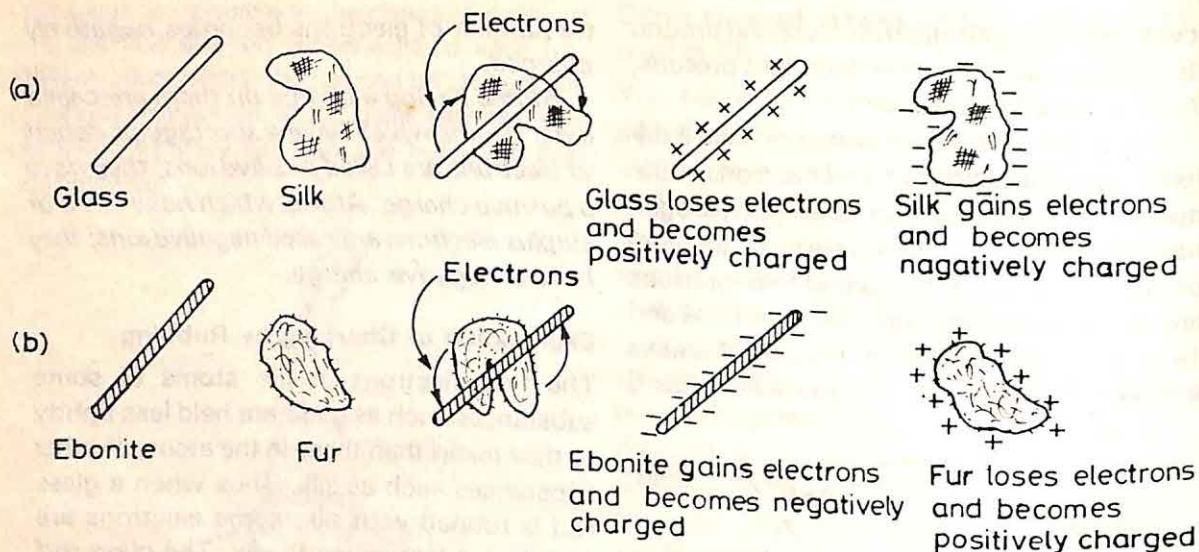


Fig. 7.5

are good conductors of electricity; they allow electricity (or charge) to flow through them. On the other hand, substances such as glass, ebonite, silk, wool, rubber, wood, plastic, mica and wax are insulators; they do not allow electricity (or charge) to flow through them.

Why are some substances conductors and others insulators of electricity? The answer lies in the fact that different substances have different numbers of free electrons in them. *Substances (such as metals) that have a large number of free electrons are conductors.* They can be used to carry or conduct charge from one place to another. *Substances that have a very small number of free electrons are insulators.* They can be used to prevent charge to flow from one place to another.

#### Charging by Conduction (or Contact)

Is rubbing the only way to charge a body? A conductor can be charged by bringing it in contact with a charged body as shown in Fig. 7.6. Suppose a metallic sphere *A* is to be charged positively. It is placed on an insulating stand as shown in the diagram. A positively

charged glass rod *B* is made to touch the sphere *A*. Some positive charge of *B* will be transferred to *A*. The rod *B* is now removed. The sphere *A* will be left with a positive charge.

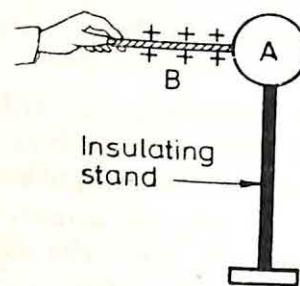


Fig. 7.6

This can be explained as follows: Since the rod *B* is positively charged, it has a deficit of electrons. When it is brought in contact with an uncharged body *A*, the free electrons of *A* will flow to *B* to make up for its deficiency. Due to a loss of electrons in *A*, it becomes positively charged.

It is clear that insulators cannot be charged by conduction (or contact) because they

do not contain any free electrons. Hence no transfer of charge can take place in insulators.

### Charging by Induction

Figure 7.7 shows two metal spheres *A* and *B* mounted on insulating stands made of

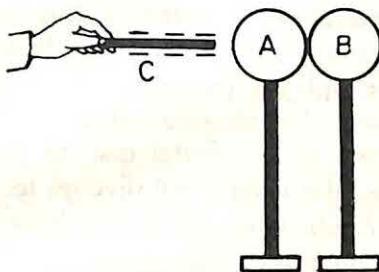


Fig. 7.7

wood or ebonite. They are placed touching each other. A negatively charged ebonite rod *C* is brought near *A* (without touching it). Sphere *B* is moved away while the rod *C* is still near the sphere *A*. If the spheres are tested, it will be found that *A* is positively charged and *B* is negatively charged.

This can be explained as follows: the negatively charged rod *C* will repel the free electrons in sphere *A* to sphere *B*. Sphere *A* having lost some electrons, becomes positively charged and sphere *B*, having gained those electrons, becomes negatively charged. We say that the charged rod has *induced* charges on spheres *A* and *B*. Notice that the charge on the sphere nearer to the inducing body is opposite to the charge on the inducing body.

### Activity 3

Take a piece of thin metal foil (the inner lid of a Bournvita tin or the silver packing of a cigarette packet will do) and shape it round like a small ball. Suspend the ball with a piece of thread.

Rub your plastic ruler with a piece of woollen cloth. The ruler becomes negatively charged. Bring the charged ruler near the ball (Fig. 7.8).

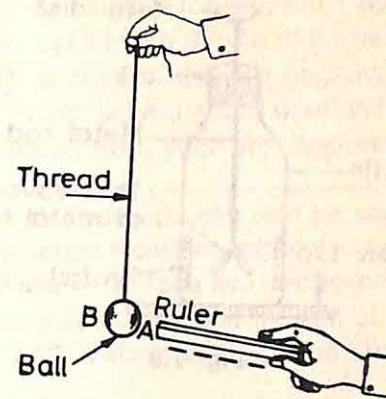


Fig. 7.8

What do you observe? The ball is attracted towards the ruler. Can you tell why? The reason is that the negatively charged ruler *induces* a positive charge on the nearer end *A* of the ball. The two unlike charges attract each other.

Touch the ruler with the ball. What do you observe now? The ball is repelled by the ruler. This happens because, on touching the ruler, some negative charge of the ruler is transferred to the ball by contact. Therefore, both the ball and the ruler have a negative charge and hence they repel each other.

### Electroscope

How can you find out whether a body is charged or uncharged or whether it carries a positive or a negative charge? Scientists use an instrument called *electroscope* to detect and test small electric charges.

A simple electroscope is shown in Fig. 7.9. It consists of a metal rod passing through a tightfitting cork in a glass bottle. To the lower end of the rod is attached a pair of thin

metallic leaves (made of gold or aluminium). The upper end of the rod has a metal disc. A part of the rod and the leaves are enclosed

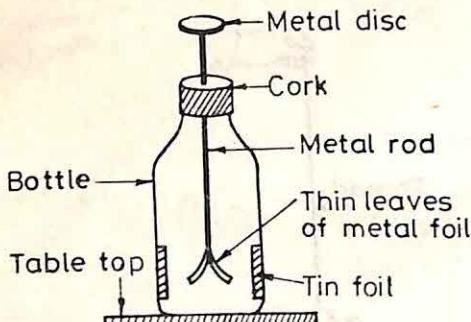


Fig. 7.9

in a bottle to protect the leaves from wind. To protect the leaves from external electric charges, the lower half of the bottle is lined with tin foil which is *earthed* so that the external charge, if any, may flow to the earth. The electroscope is placed on a wooden table.

The electroscope can be used to detect whether a body is charged or not. Take a glass rod and rub it with silk. Let the rod touch the metal disc of the electroscope as shown in Fig. 7.10a. You will notice that the leaves of

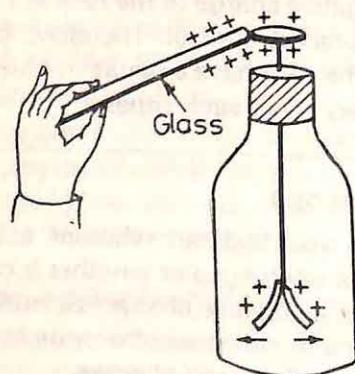


Fig 7.10 (a)

the electroscope diverge (get separated) as shown in the diagram. The leaves diverge

because when the positively charged glass rod is touched to the metal disc, some charge is transferred to the disc and to the leaves through the metal rod. Both the leaves have a positive charge and they repel each other and, therefore, diverge. If the metal disc is touched with the hand, the leaves collapse (or come closer together). This happens because the charge on the leaves flows to the earth through the human body.

Similarly, if an ebonite rod rubbed with fur is touched to the metal disc of the electroscope, the leaves will diverge as shown in Fig. 7.10b. Both the leaves now have a negative charge.

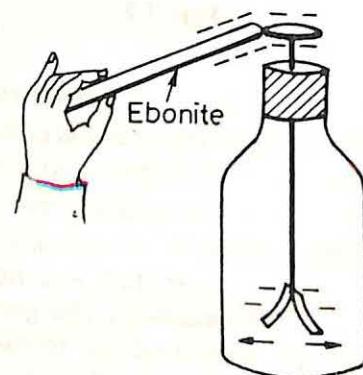


Fig. 7.10 (b)

Thus, to find out whether a body is charged or not, allow it to touch the metal cap of an electroscope. If the leaves diverge, the body is charged and if they do not diverge, the body has no charge; it is neutral. The greater the charge, the greater is the divergence of the leaves.

Suppose you have a charged body and you wish to find out whether it has a positive charge or a negative charge. For this purpose, it is necessary to charge the electroscope either positively or negatively. Suppose you have a positively charged electroscope. Bring the body (whose charge is to be determined)

in contact with the metal disc of the electroscope. If the divergence of the leaves increases, the body has a positive charge; but if the divergence of the leaves decreases, the body has a negative charge.

#### Activity 4: Making an Electroscope

You can make your own electroscope at home. You will need a wide-mouthed glass bottle (an empty inkpot will do), a piece of stiff card, an aluminium clothes clip, a thin metal foil piece (a chocolate or cigarette wrapper will do).

Remove the lid of the bottle. Cut a circle out of the stiff card that will cover the mouth of the bottle. At the centre of the card make a hole just big enough to hold the aluminium clip (Fig. 7.11). Cut a strip  $\frac{1}{2}$  cm wide and

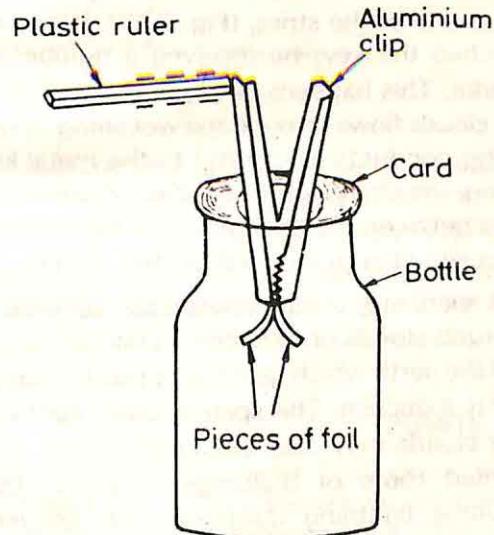
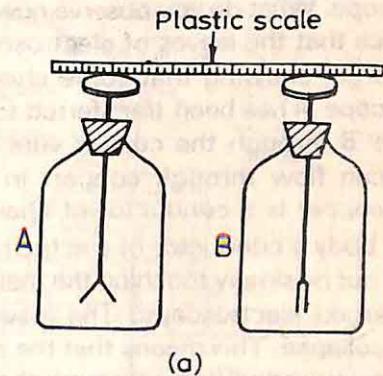


Fig. 7.11

5 cm long from the thin metal foil. Fold it in two and hold it between the jaws of the clip. Fix the clip in the card. Use cellophane or gum to fix the card on the mouth of the bottle. Your electroscope is now ready for use.

Now take your plastic ruler and rub it with a woollen garment. Touch the ruler with the clip as shown in Fig. 7.11. What do you find? Next, take a glass rod and rub it with a piece of silk. Let it touch the clip of the electroscope which is already charged negatively by the ruler. What do you notice now? What do you conclude from your observations?

An electroscope can also be used to find out whether a certain material is a conductor or an insulator. Take two electroscopes *A* and *B* and place them side by side as shown in Fig. 7.12. Take a charged rod and touch it



(a)

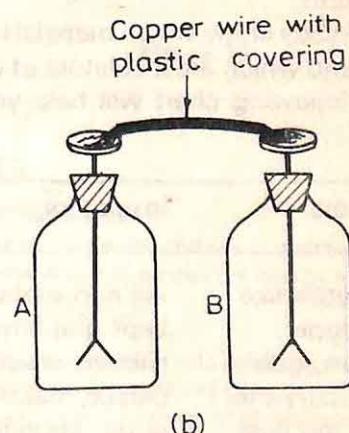


Fig. 7.12

with the metal disc of *A*, it is charged and its leaves diverge. Electroscope *B* is uncharged, its leaves remain collapsed.

Now take a plastic ruler and use it to connect the discs of *A* and *B* as shown in Fig. 7.12a. The leaves of electroscope *B* still remain collapsed, showing that charge cannot flow from *A* to *B* through the plastic ruler. In other words, plastic is an insulator.

Next, take a piece of plastic-covered copper wire and remove the plastic covering from its ends. Hold the wire from the middle and place it on the discs of the electroscopes as shown in Fig. 7.12b. Make sure that the naked wires at the ends touch the disc of each electroscope. What do you observe now? You will notice that the leaves of electroscope *B* also diverge, showing that some charge of electroscope *A* has been transferred to electroscope *B* through the copper wire. Thus charge can flow through copper. In other words, copper is a conductor of charge.

Is our body a conductor of electricity? We can find out by simply touching the metal disc of a charged electroscope. The leaves are seen to collapse: This means that the charge on the electroscope flows through the body to the earth.

You already know which materials are conductors and which are insulators of electricity. The following chart will help you recall them.

Conductors	Insulators
1. All metals like silver, copper, aluminium, gold, iron, mercury etc. Silver is the best conductor	All non-metals (except graphite) like rubber, wood, plastic, bakelite, glass, ebonite, mica, cotton, silk, air, other gases, wax, wool, etc.

2. A non-metal like Pure water graphite (it is a form of carbon used in lead pencils)
3. Water solutions of acids, bases and salts Dry and dead animal and plant bodies
4. Living animal and plant bodies

## Atmospheric Electricity

Due to friction or rubbing between clouds and the wind, clouds acquire large electric charge. In 1752, an American scientist Benjamin Franklin showed that clouds have electrical charges. For this purpose, he flew a kite in a thunderstorm and tied a metal key near the other end of the string (Fig. 7.13). When he touched the key, he received a number of sparks. This happens because the charge of the clouds flows through the wet string (a wet string conducts electricity) to the metal key where the charge gets collected. A spark occurs between the charge on the key and the opposite charge induced on the finger.

A spark may occur between two oppositely charged clouds or between a charged cloud and the earth which gets the opposite charge due to induction. This spark is called *lightning*. The clouds may also *induce* charge on the pointed roofs of buildings or trees. The resulting lightning discharge can be very dangerous. It can kill men and animals. It can cause fire and shatter buildings.

### The Lightning Conductor

Tall buildings can be protected from lightning by a lightning conductor. A lightning conductor is a long flat thick strip of copper with sharp points or spikes projecting above the

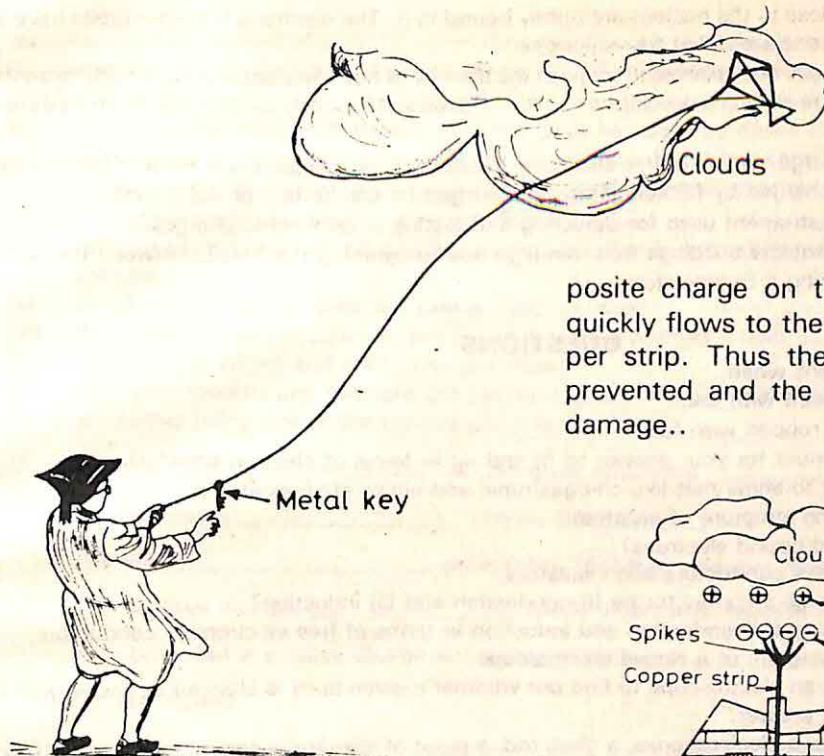


Fig. 7.13

highest part of a building. The lower end is connected to a copper plate buried deep into the earth to provide a good earth connection (Fig. 7.14). When a highly charged cloud passes over the building, it induces an op-

posite charge on the spikes. This charge quickly flows to the earth through the copper strip. Thus the lightning discharge is prevented and the building is saved from damage..

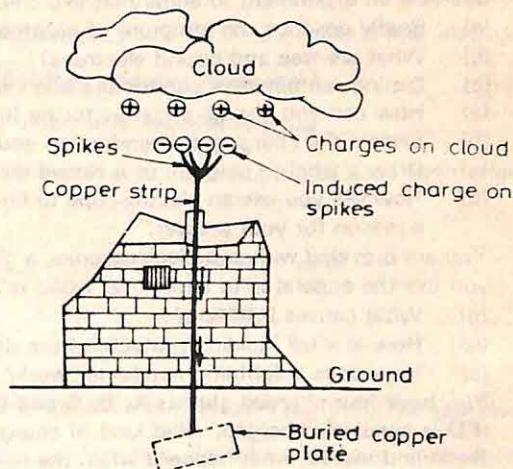


Fig. 7.14

### POINTS TO REMEMBER

1. Materials like glass, ebonite or plastic can be charged by rubbing or friction.
2. When a glass rod is rubbed with silk, the glass acquires a positive charge and the silk acquires and equal negative charge. If an ebonite rod is rubbed with fur, the ebonite acquires a negative charge and fur an equal positive charge.
3. Like charges repel, unlike charges attract.
4. An atom consists of a positively charged nucleus with negatively charged electrons revolving around it in various orbits. The nucleus consists of protons and neutrons. The protons are positively charged and neutrons are uncharged. The mass of a neutron is nearly equal to that of a proton. The mass of an electron is about  $1/1840$  of that of a proton.
5. In a normal or neutral atom, the number of electrons is equal to the number of protons.
6. The atoms of different elements have a different number of protons and neutrons in their nuclei.

7. The electrons orbiting close to the nucleus are tightly bound to it. The electrons in higher orbits have very little force of attraction and are called free electrons.
8. Electrification by friction can be explained in terms of the transfer of free electrons from one body to another. The body which gains extra electrons develops a negative charge and the body which loses electrons develops a positive charge.
9. Conductors have a very large number of free electrons. Insulators have a negligible number of free electrons.
10. Conductors cannot be charged by friction. They are charged by conduction or induction.
11. An electrostatics is an instrument used for detecting and testing small electric charges.
12. A lightning conductor protects buildings from damage due to lightning discharge, between the building and charged clouds, during a thunderstorm.

### QUESTIONS

1. (a) State what happens when
  - (i) a glass rod is rubbed with silk.
  - (ii) an ebonite rod is rubbed with fur.
 (b) How will you account for your answer to (i) and (ii) in terms of electron transfer?
2. Describe an experiment to show that like charges repel and unlike charges attract.
3. (a) Briefly describe the structure of an atom.  
 (b) What are free and bound electrons?  
 (c) Distinguish between conductors and insulators.
4. (a) How can you charge a conductor by (i) conduction and (ii) induction?  
 (b) Explain the charging by conduction and induction in terms of free electrons in conductors.
5. (a) Draw a labelled diagram of a simple electrostatics.  
 (b) How will you use an electrostatics to find out whether a given body is charged or uncharged? Give a reason for your answer.
6. You are provided with two electrostatics, a glass rod, a piece of silk, and wooden metre scale. How will you use the apparatus to show that wood is an insulator of electricity? Give reasons for your answer.
7. (a) What causes lightning?  
 (b) How is a tall building protected from damage due to lightning?  
 (c) How does a lightning conductor work?
8. You have four charged objects A, B, C and D. You find that A repels B and attracts C but C repels D. If D is positively charged, what kind of charge does B have?
9. State and explain what happens when the following are in turn, placed in contact with the metal disc of a negatively charged electrostatics: (a) a glass rod rubbed with silk, (b) an ebonite rod rubbed with fur, (c) an uncharged metal rod, and (d) a wooden rod.
10. An electrostatics A has a positive charge and another electrostatics B has an equal negative charge. What would happen if their metal discs are connected by a metal wire? Give reasons for your answer.
11. Figure 7.15 shows a metal rod AB on an insulated stand. The end A of the rod is in contact with the metal

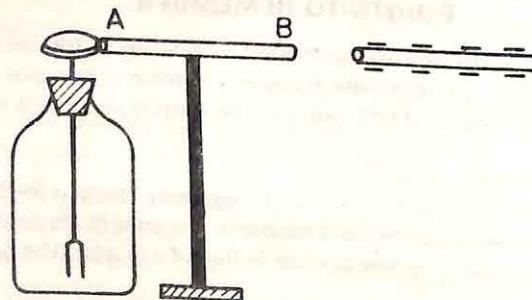


Fig. 7.15

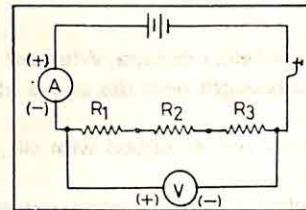
disc of an uncharged electroscope. What will happen to the leaves of the electroscope if a negatively charged ebonite rod is brought near the end B of the rod? Give reasons for your answer.

12. *Mark true or false.*

- (i) When a glass rod is rubbed with silk, the glass becomes positively charged and the silk remains uncharged.
- (ii) When an ebonite rod is rubbed with fur, electrons are transferred from fur to ebonite.
- (iii) A charged body cannot attract an uncharged body.
- (iv) When a neutral conductor is touched to the disc of a charged electroscope, the leaves immediately collapse.
- (v) Small charges can be detected with an electroscope.
- (vi) An uncharged electroscope may be used to determine whether a body a positive or a negative charge.
- (vii) Like charges attract and unlike charges repel.
- (viii) Electrons, protons and neutrons are packed together in the nucleus of an atom.

13. *Fill in the blanks using one of the choices given in brackets:*

- (i) When a glass rod is rubbed with silk, the glass acquires a \_\_\_\_\_ charge and the silk acquires a \_\_\_\_\_ charge because \_\_\_\_\_ loses some electrons and the \_\_\_\_\_ gains them. (positive, negative, glass, silk)
- (ii) Two positive charges \_\_\_\_\_ each other, two negative charges \_\_\_\_\_ each other but a positive charge and a negative charge \_\_\_\_\_ each other. (attract, repeal)
- (iii) The charge on an electron is \_\_\_\_\_ (positive, negative, zero).
- (iv) Neutral atoms have the same number of \_\_\_\_\_ and \_\_\_\_\_ (electrons, protons, neutrons).
- (v) When a positively charged body is placed in contact with the metal disc of a positively charged electroscope, the leaf divergence \_\_\_\_\_ (increases, decreases, remains unchanged).
- (vi) When an uncharged insulator is placed in contact with the metal disc of a negatively charged electroscope, the leaf divergence \_\_\_\_\_ (increases, decreases, remains unchanged).



# 8

# Current Electricity

In the last chapter you have studied how bodies can be charged. You have learnt that there is a force between charges at rest. These charges will move if free to do so. You have seen that if a conductor is connected to the metal discs of two electroscopes, one charged and the other uncharged, then the charge flows (or moves) from the charged electroscope to the uncharged electroscope. *A moving charge constitutes a current.* In this chapter we shall study moving charges. The branch of physics which deals with the study of moving charges is known as *current electricity*.

In order to study moving charges, it is necessary to introduce a new concept, the *electrical potential*. You will later learn about the usefulness of this concept.

## Electrical Potential

Suppose we have two positively charged conductors supported on insulating stands. If we place them in contact, the charge will flow from one to the other. This can be shown with the help of an electroscope. What causes the charge to flow? What determines the direction of the flow of charge? These questions can be answered in terms of what is called the *electrical potential* of a charged body. The following examples will help you to under-

stand the meaning of electrical potential.

### EXAMPLE 1

Take two jars containing water and connected to each other by a tube fitted with a stopcock as shown in Fig. 8.1. When the stopcock is

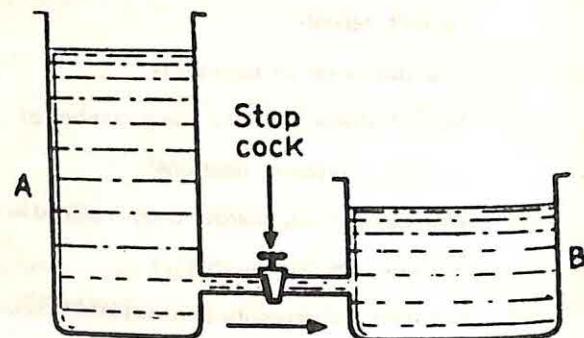


Fig. 8.1

opened, water will flow from jar A (in which the water level is higher) to jar B (in which the water level is lower) even though jar A may have less water than jar B. The flow of water stops when the levels are the same in both jars. Thus, it is the height of the level and not the quantity of the liquid which determines the direction in which water will flow.

### EXAMPLE 2

Heat a piece of metal and put it in a beaker

containing water at room temperature. The temperature of water rises. Heat will flow from the metal (which is at a higher temperature) to water (which is at a lower temperature) even though the quantity of heat in water (which is determined by its mass, specific heat and temperature) may be more than that in the metal piece. Thus it is the temperature and not the quantity of heat which determines the direction in which heat will flow.

Electrical potential plays the same role in the flow of charge as is played by height of the level in the flow of a liquid or by temperature in the flow of heat. Just as the direction of the flow of water is independent of the total quantity of water, or the direction of the flow of heat is independent of the total quantity of heat, the direction of the flow of charge does not depend upon the quantity of charge on the two charged bodies when they are brought into contact. The direction of the flow of charge depends upon the *electrical potential* of the two charged bodies. *Charge flows from a body having a higher electrical potential to a body having a lower electrical potential.*

Thus, *electrical potential is the condition which determines the direction of the flow of charge.* A positively charged body is said to have a positive potential and a negatively

charged body has a negative potential. For practical purposes, the earth is taken to be at zero electrical potential.

Figure 8.2a shows what happens when a positively charged body is connected to the earth by means of a conducting wire. The positively charged body is at a higher positive potential than the earth which is at zero potential. Therefore, positive charge will flow from the body to the earth, which is the same thing as saying that the negative charge (electrons) will flow from earth to the body. This flow continues till the potentials are equalized. On the other hand, when a negatively charged body is connected to earth, electrons will flow from the body to the earth, until the two bodies have reached the same potential. This is shown in Fig. 8.2b.

#### Potential Difference

It is clear that charge will flow from one body to another if there is a difference of potential between them. Similarly, charge will flow through a conducting wire if a potential difference is maintained between its ends. A cell serves this purpose; it supplies the energy needed to maintain a difference of potential.

#### Units of Charge and Potential Difference

You know that an electron has a negative

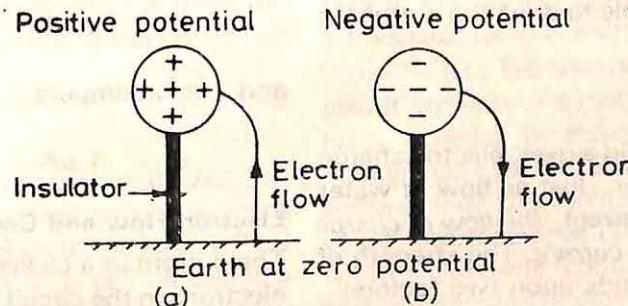


Fig. 8.2

charge. Scientists used this charge as a unit; but the charge of an electron is too small to be used as a unit for practical purposes. Therefore, scientists use an unit of charge called the *coulomb* (symbol C). A coulomb is taken to be the standard unit of charge.

*coulomb is equal to the charge of  $6.24 \times 10^{18}$  electrons.* Do you know what it represents?  $6.24 \times 10^{18}$  is the same thing as  $624 \times 10^{16}$  or 624 followed by 16 zeros or 6,240,000,000,000,000,000. A submultiple of coulomb called *microcoulomb* (symbol  $\mu\text{C}$ ) is also used. 1 microcoulomb is one-millionth of a coulomb.

$$1 \text{ microcoulomb} = \frac{1}{1,000,000} \text{ coulomb}$$

or  $1 \mu\text{C} = 10^{-6}\text{C}$

You know that in order to move a body, work has to be done on it. Hence work must be done to move a charge. The unit of potential difference is defined in relation to this work. The standard unit of potential difference is called the *volt* (symbol V).

*The potential difference between two points is said to be 1 volt if 1 joule of work is done to move 1 coulomb of charge from one point to the other.*

Look at a torch cell. It is marked 1.5 V or 1.5 volts. This means that there is a potential difference of 1.5 volts between its terminals. If this potential difference did not exist, the cell would not be able to drive the current in the circuit.

## Electric Current

Just as water flows in a river, electric charge flows in a conductor. Just as flow of water constitutes water current, *the flow of charge constitutes electric current.* The strength of water current depends upon two factors:

- the amount of water flowing and
- the rate at which it flows.

Similarly the strength of electric current depends upon two factors:

- the amount of charge flowing in a conductor, and
- the rate at which it flows.

If a charge  $Q$  flows through a conductor in time  $t$ , the current  $I$  in the conductor is given by

$$\text{Current} = \frac{\text{charge}}{\text{time}}$$

or  $I = \frac{Q}{t}$

The standard unit of current is called *ampere* (symbol A).

$$1 \text{ ampere} = \frac{1 \text{ coulomb}}{1 \text{ second}}$$

*The current in a conductor is 1 ampere if 1 coulomb of charge flows through the conductor in 1 second.* If two coulombs of charge flow through a conductor in 1 second, the current in the conductor is 2 amperes. Thus a current of 1 ampere means that  $6.24 \times 10^{18}$  electrons move through any point of the conductor every second.

Sometimes smaller units of current are used.

They are

$$1 \text{ milliampere} = \frac{1}{1000} \text{ ampere}$$

$$\text{or } 1 \text{ m A} = 10^{-3}\text{A}$$

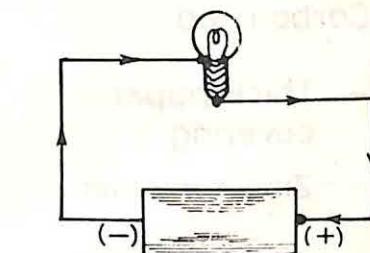
$$\text{and } 1 \text{ microampere} = \frac{1}{1,000,000} \text{ ampere}$$

$$\text{or } 1 \mu\text{A} = 10^{-6}\text{A}$$

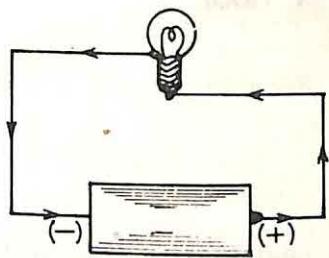
## Electron Flow and Conventional Current

The current in a closed circuit is the flow of electrons in the circuit. The cell is the source of electrons which flow from its negative terminal to its positive terminals as shown in Fig.

8.3a. The arrows in the diagram show the direction in which the electrons move in the circuit.



(a) Direction of electron flow



(b) Direction of conventional current

Fig. 8.3

However, before scientists had found out about electrons, they used to mark the direction of the current in the opposite way from the positive to the negative terminal. This is called the *conventional current*. This is shown in Fig. 8.3b. From now on we shall mark the direction of the current in a circuit in this manner.

## Electric Cells

In order to obtain a continuous supply of current in a circuit, a potential difference must be maintained at the ends of the circuit. This is done with the help of a cell. A cell is a device in which a potential difference is maintained between its two terminals by a conversion of chemical energy into electrical energy.

The simplest cell was devised by Alessandro Volta and is called a voltaic cell. It consists of two plates, one of copper and the other of zinc, both dipped in dilute sulphuric acid contained in a glass vessel and kept apart as shown in Fig. 8.4. The two plates are call-

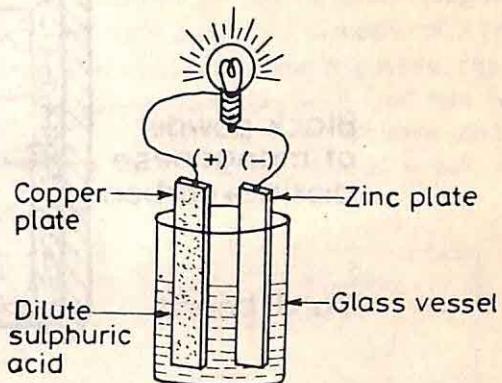


Fig. 8.4

ed *electrodes* and the solution in which they are dipped is called *electrolyte*. As a result of a chemical reaction, a potential difference is developed between the plates. If a bulb is connected to the plates as shown, it begins to glow. The copper plate is the positive electrode (or terminal) and the zinc plate is the negative electrode.

The cell described above is a wet cell and cannot be easily carried from one place to another because it uses a liquid as an electrolyte. The type of cell you use in a torch or a transistor radio is a dry cell; it contains no liquid. Figure 8.5 shows the inside of a dry cell. It consists of a carbon rod inserted in a black powder (a mixture of carbon and manganese dioxide). The rod, along with the surrounding black mixture, is placed in a zinc vessel and the space between them is filled with a white paste (consisting of starch, flour and ammonium chloride). The top of the cell is sealed with an insulating material. Thick insulating paper is inserted at the bottom between

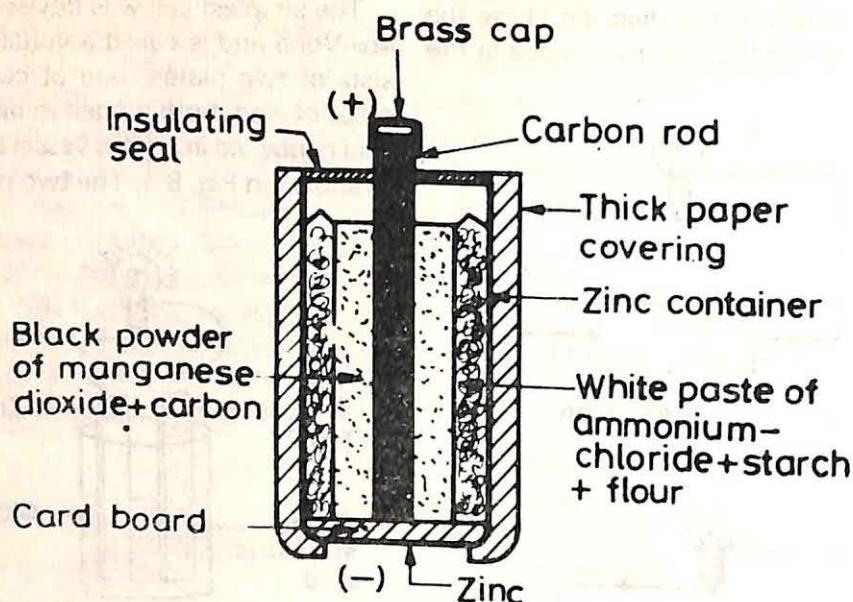


Fig. 8.5

ween the carbon rod and the zinc vessel. The zinc vessel is surrounded by thick insulating paper. The carbon rod is the positive terminal and the zinc vessel the negative terminal of the cell. As a result of a chemical reaction between the chemicals of the cell, a potential difference of 1.5 volts is developed between its terminals.

board wrapping. You will now be able to see a metal container; it is made of zinc. Tear off a part of the zinc casing with the help of pliers. Do you see a whitish jellylike substance? Can you name it? With a knife remove the white jelly. Do you see a black sticky power? What does it consist of? Now grip the brass cap firmly at the top with a pair of pliers and pull out the black rod of carbon (Fig. 8.6).

#### Activity 1: Parts of a Dry Cell

Take an old used cell. First take off the card

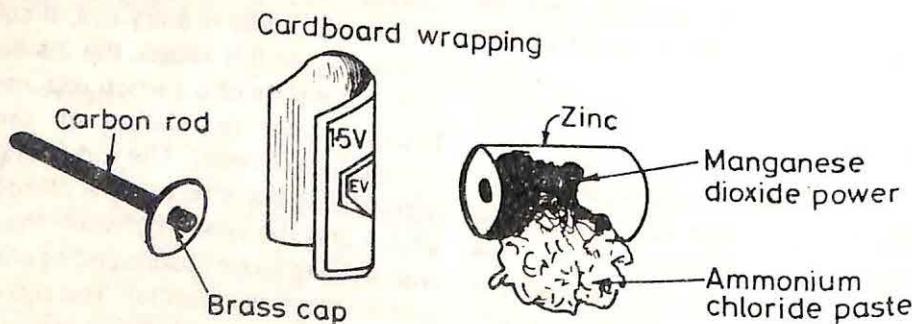


Fig. 8.6

### Activity 2

You can make your own cell. Cut a piece of zinc from the outer casing of an old used cell and insert it in a fresh juicy lemon. Make a hole in the lemon and insert the carbon rod as shown in Fig. 8.7. Your cell is ready. The

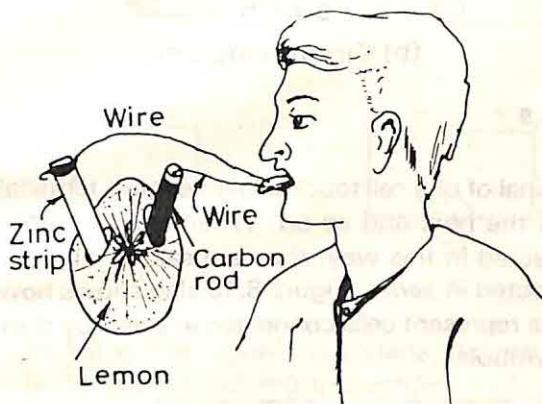


Fig. 8.7

lemon juice is the electrolyte and zinc and carbon its two terminals. If you touch your tongue to the two terminals as shown in the diagram, you will feel a slight tickling because a weak current flows through your tongue.

The cells so far described are called *primary cells*. When the cell is used, its chemicals are used up and the cell stops working. The cells used in laboratories and cars are *secondary cells*. They can be recharged and can be reused. These cells are also called *storage cells* or *accumulators*.

### How to Draw a Circuit Diagram

Scientists use special symbols to represent various things they use in their experiments. In chemistry, you use symbols to represent various elements. H stands for hydrogen, O for oxygen, Na for sodium and so on. Similar-

ly, in physics, we use symbols to represent the various parts of an experiment. In electricity we use symbols to represent the various parts of a circuit.

You have already used a simple circuit consisting of a cell, a torch bulb, a switch and lengths of wires. To draw a circuit diagram, we must write down the symbols of a cell, a bulb, a switch and connecting wires. Figure 8.8 shows these symbols. A cell has two terminals—a positive (+) terminal and a negative (−) terminal. Look at a cell and

Apparatus	Symbol
A cell	
Open switch	
Closed switch	
A bulb	

Fig. 8.8

locate its positive and negative terminals. The first picture in Fig. 8.8 shows the symbol we use for a cell. The long vertical line is the positive terminal and the short line is the negative terminal. The second picture shows an open and closed switch. The bulb is shown

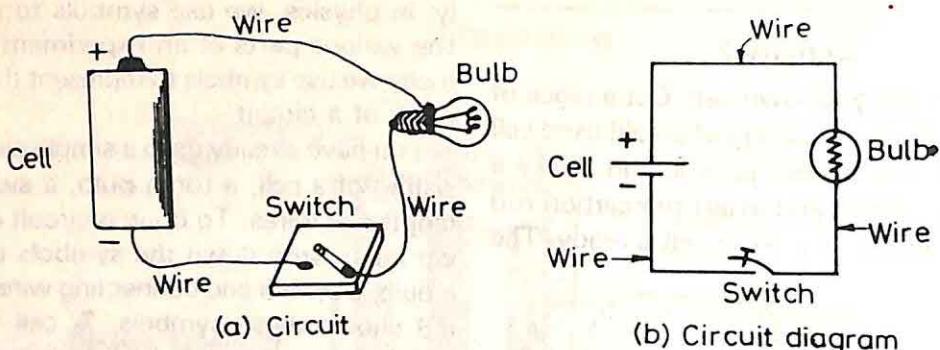


Fig. 8.9

in the third picture. The connecting wires are shown by lines.

Using these symbols a drawing of a circuit shown in Fig. 8.9a can be changed into a *circuit diagram* shown in Fig. 8.9b.

A group of two or more cells used together is called a battery. In a torch, two or more cells are used together. The cells are connected as shown in Fig. 8.10. The positive ter-

minal of one cell touches the negative terminal of the next and so on. When cells are connected in this way, they are said to be connected in *series*. Figure 8.10 also shows how we represent cells connected in series by their symbols.

### Activity 3

Take three fresh cells and a torch bulb and two pieces of wire. You have already learnt in class VI how a bulb is connected to a cell so that it can glow. First connect only one cell to the bulb. Then connect the bulb to two cells in series and finally connect the bulb to three cells connected together in series (Fig. 8.11). What do you observe? Will the bulb glow with equal brightness in the three cases? You will find that the brightness is maximum if you use three cells in series. The bulb is quite dim if only one cell is used. Can you tell why this happens? Figure 8.11 also shows the circuit diagram in each case.

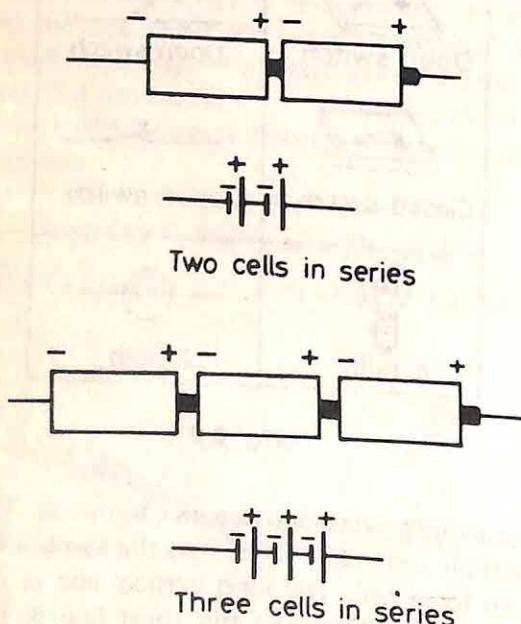


Fig. 8.10

The voltage of a fresh dry cell is 1.5 V. This means that a potential difference of 1.5 volts exists across its terminals. If two cells are connected in series, their combined voltage will be  $1.5 + 1.5 = 3$  V. The voltage of three cells connected in series will be  $1.5 + 1.5 + 1.5 = 4.5$  V.

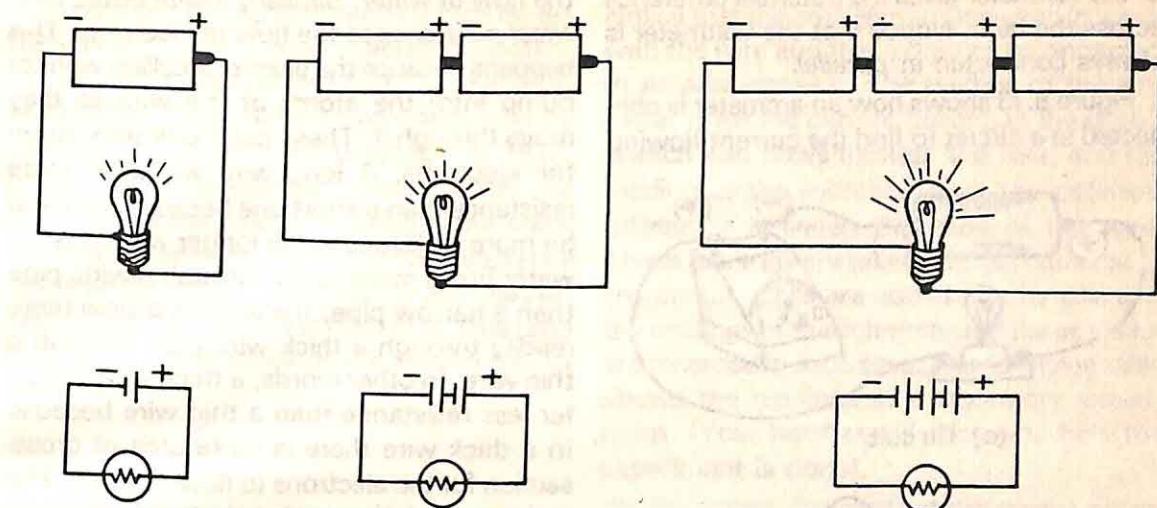


Fig. 8.11

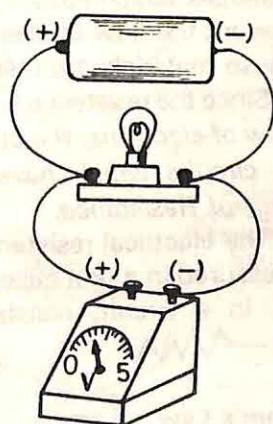
= 4.5 V. The higher the voltage, the greater is the current flowing through the bulb and the brighter it glows.

### Voltmeter and Ammeter

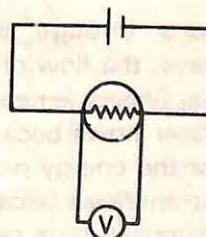
A voltmeter is an instrument used for measuring the potential difference between two points or terminals. It has a scale which is graduated in volts. The *ammeter* is an instru-

ment used for measuring the current flowing through a conductor or circuit. It has a scale which is graduated in amperes.

Figure 8.12 shows how a voltmeter is connected in a circuit to find the potential difference between the ends of the filament of a bulb. The terminal marked (+) on the voltmeter is connected to that terminal of the bulb which is connected to the (+) terminal of the cell and the terminal of the voltmeter marked (−) is connected to that terminal of the bulb which is connected to the (−) terminal of the cell. The reading of the pointer



(a) Circuit



(b) Circuit diagram

Fig. 8.12

of the voltmeter gives the potential difference across the bulb. Notice that the voltmeter is always connected in parallel.

Figure 8.13 shows how an ammeter is connected in a circuit to find the current flowing

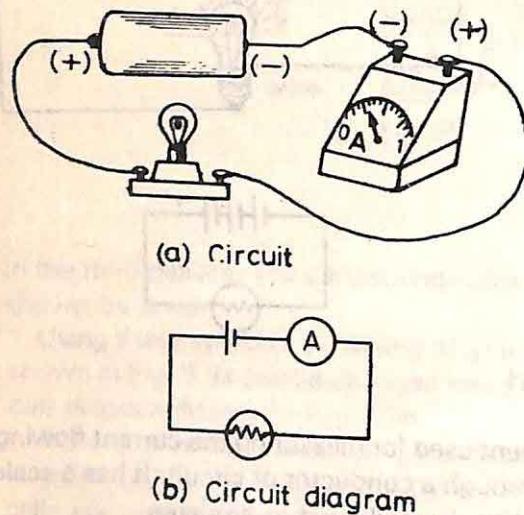


Fig. 8.13

in it. The terminal of the ammeter marked (–) is connected to the (–) terminal of the cell and the terminal marked (+) is connected to the (+) terminal of the cell through the bulb. The reading of the pointer of the ammeter gives the current flowing in the circuit. Notice that an ammeter is always connected in series.

## Electrical Resistance

The flow of electrons through a wire resembles, in some ways, the flow of water in a pipe. In both cases, energy is needed to maintain the flow. Water flows because of gravitational energy or the energy provided by a pump. Electric current flows because of the electrical energy supplied by a cell.

The friction between the water and the walls of the pipe reduces the flow of water. In other words, the pipe offers resistance to

the flow of water. Similarly a wire offers *electrical resistance* to the flow of electrons. This happens because the electrons collide with (or bump into) the atoms of the wire as they move through it. These collisions slow down the electrons. A long wire will offer more resistance than a short one because there will be more collisions in the longer wire. Just as water flows more easily through a wide pipe than a narrow pipe, the electrons flow more readily through a thick wire than through a thin wire. In other words, a thick wire will offer less resistance than a thin wire because in a thick wire there is more area of cross-section for the electrons to flow through. The resistance of a wire also depends upon the material of which it is made. Thus we find that the *resistance of a wire*.

- increases when the length of the wire is increased;
- decreases when the thickness of the wire is increased;
- depends on the material of which the wire is made.

Good conductors of electricity are those which have a very low resistance and allow the electrons to flow through them very easily. Materials which have a very high resistance prevent the flow of electrons through them. These materials are insulators.

Since the resistance in a circuit opposes the flow of electrons, the current strength is low in circuits which have a high resistance. *Unit of Resistance*.

The electrical resistance of a conductor is measured in a unit called *ohm*. Its symbol is  $\Omega$ . In a circuit, resistance is represented as

## Ohm's Law

In an electrical circuit, the cell is the source of electrical energy which maintains a potential difference between the ends of a conduc-

tor. It is the potential difference which drives the current in the circuit. Therefore, potential difference and current must be related to each other. This relation was discovered by George Simon Ohm of Germany in 1827. From his experimental observations, he discovered a law, known as *Ohm's Law* which states that *the ratio of the potential difference between the ends of a conductor and the current flowing through it is constant*. This ratio is called the resistance of the conductor. In symbols,

$$\frac{V}{I} = R$$

Where  $V$  = potential difference in volts,  
 $I$  = current in amperes, and  
 $R$  = resistance in ohms

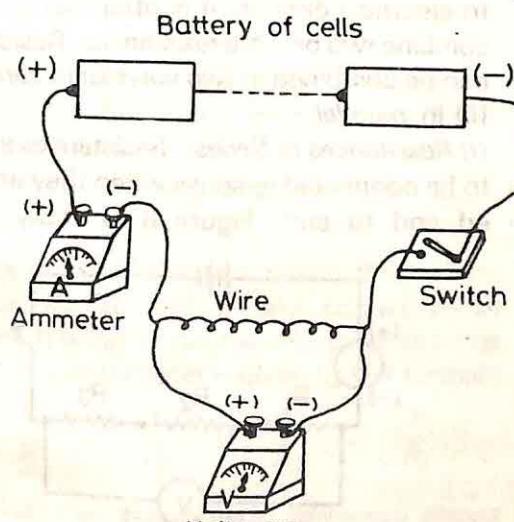
This relation tells us that if the potential difference between the ends of a conductor is doubled, the current flowing in it is also doubled and so on.

#### Verification of Ohm's Law and Determination of Resistance of a Wire

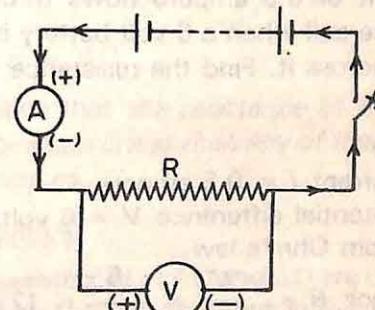
Set up the circuit as shown in Fig. 8.14.

Notice that the ammeter is connected in *series* with the wire and the voltmeter is connected in *parallel* across it. The reading of the ammeter gives the current flowing in the circuit (which also flows through the wire) and the reading of the voltmeter gives the potential difference between the ends of the wire. These readings are taken with just one cell in the circuit. Cells are added one by one and the readings of the voltmeter and the ammeter are recorded in each case. The following table shows the readings in a laboratory experiment. (Your teacher will show you how the experiment is done).

No. of cells used	Voltmeter reading (V)	Ammeter reading (I)	Ratio $R = \frac{V}{I}$
1	1.5 V	0.5 A	$\frac{1.5}{0.5} = 3 \Omega$
2	3.0 V	1.0 A	$3 \Omega$
3	4.5 V	1.5 A	$3 \Omega$
4	6.0 V	2.0 A	$3 \Omega$
5	7.5 V	2.5 A	$3 \Omega$



(a) Circuit



(b) Circuit diagram

Fig. 8.14

It is found that the ratio  $\frac{V}{I}$  remains constant, although  $V$  and  $I$  both change. This verifies Ohm's law. The constant ratio  $R$  determines the resistance of the wire.

$$\text{From Ohm's law } R = \frac{V}{I}$$

It follows that if  $V = 1$  volt and  $I = 1$  ampere, then  $R = 1$  ohm. Thus, *the resistance of a conductor is said to be 1 ohm if a current of 1 ampere flows through it when a potential difference of 1 volt is maintained between its ends.*

### EXAMPLE 3

A current of 2 amperes flows through a conductor for 5 minutes. How many coulombs of charge have passed through the conductor?

*Solution*

$$\text{Current } I = 2 \text{ amperes}$$

$$\text{Time } t = 5 \text{ minutes}$$

$$= 5 \times 60 = 300 \text{ seconds}$$

$$\begin{aligned} \text{Now charge } Q &= \text{current} \times \text{time} \\ &= I \times t \\ &= 2 \times 300 = 600 \text{ coulombs} \end{aligned}$$

### EXAMPLE 4

A current of 0.5 ampere flows through a resistance coil when a 6 volt battery is connected across it. Find the resistance of the coil.

*Solution*

$$\text{Current } I = 0.5 \text{ ampere}$$

$$\text{Potential difference } V = 6 \text{ volts}$$

From Ohm's law,

$$\text{Resistance } R = \frac{V}{I} = \frac{6}{0.5} = 12 \text{ ohms}$$

### EXAMPLE 5

A current of 0.4 ampere is flowing through

a wire of resistance 10 ohms. Find the potential difference across the wire.

*Solution*

$$\text{Current } I = 0.4 \text{ ampere}$$

$$\text{Resistance } R = 10 \text{ ohms}$$

From Ohm's law

$$R = \frac{V}{I}, \text{ where } V = \text{potential difference}$$

$$\therefore V = I \times R = 0.4 \times 10 = 4 \text{ volts}$$

### EXAMPLE 6

A potential difference of 200 volts is maintained across a heater coil of resistance 40 ohms. Find the current in the coil.

*Solution*

$$\text{Potential difference } V = 200 \text{ volts}$$

$$\text{Resistance } R = 40 \text{ ohms}$$

From Ohm's law,

$$R = \frac{V}{I}, \text{ where } I = \text{current}$$

$$\therefore I = \frac{V}{R} = \frac{200}{40} = 5 \text{ amperes}$$

### Combination of Resistances

In electrical circuits, it is often necessary to combine two or more resistances. Resistances can be combined in two ways (i) in *series* and (ii) in *parallel*.

(i) *Resistances in Series* Resistances are said to be connected in series when they are joined end to end. Figure 8.15 shows three

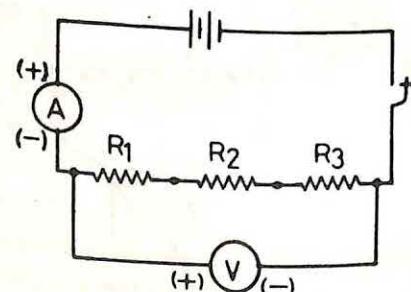


Fig. 8.15

resistances  $R_1$ ,  $R_2$  and  $R_3$  connected in series. What is the resistance of the combination? First determine the value of each resistance by the experiment shown in Fig. 8.14. Let their values be  $R_1 = 2 \Omega$ ,  $R_2 = 3 \Omega$  and  $R_3 = 5 \Omega$ .

Now connect the three resistances in series and determine the resistance  $R$  of the combination by using the circuit shown in Fig. 8.14. You will find that the value of  $R = 10 \Omega$  which is  $2\Omega + 3\Omega + 5\Omega = 10\Omega$ . This shows that

$$R = R_1 + R_2 + R_3$$

Remember that the *current in each resistance is the same*. When resistances are connected in series, the total resistance is equal to the sum of the individual resistances.

(ii) *Resistances in Parallel* What is the resistance of the combination when resistances are connected in parallel? Figure 8.16

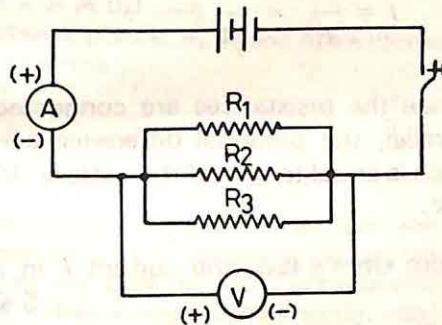


Fig. 8.16

shows a circuit diagram which three resistances  $R_1$ ,  $R_2$  and  $R_3$  are connected in parallel. It is found that the effective resistance  $R$  of the combination is given by the formula

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

It is clear that the potential difference across each resistance is the same. When resistances are connected in parallel, the reciprocal of the

resistance of the combination is equal to the sum of the reciprocals of the individual resistances.

#### EXAMPLE 7

Three resistances of  $8 \Omega$ ,  $12 \Omega$  and  $24 \Omega$  are connected (a) in series and (b) in parallel. Find the resistance of the combination in each case.

*Solution*

$$R_1 = 8 \Omega$$

$$R_2 = 12 \Omega$$

$$R_3 = 24 \Omega$$

(a) When resistances are connected in series, the resistance of the combination is given by

$$R = R_1 + R_2 + R_3 \\ = 8 + 12 + 24 = 44 \Omega$$

(b) When the resistances are connected in parallel, the resistance of the combination is given by

$$\begin{aligned} \frac{1}{R} &= \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \\ &= \frac{1}{8} + \frac{1}{12} + \frac{1}{24} \\ &= \frac{3 + 2 + 1}{24} = \frac{6}{24} = \frac{1}{4} \end{aligned}$$

$$\text{or } R = 4 \Omega$$

Notice that the resistance of the parallel combination is less than any of the individual resistances.

#### EXAMPLE 8

Two resistances of  $4 \Omega$  and  $6 \Omega$  are connected by a 3 volt battery as shown in Fig. 8.17. Find

- the current in the circuit,
- the potential difference across the resistance of  $4 \Omega$  and
- the potential difference across the resistance of  $6 \Omega$ .

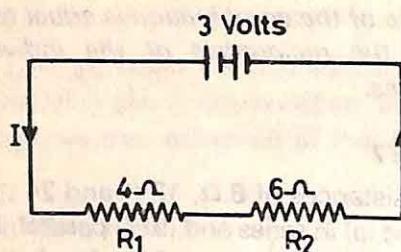


Fig. 8.17

**Solution**

(a) Total resistance ( $R$ ) in the circuit  $= 4 + 6 = 10 \Omega$  Potential difference ( $V$ )  $= 3$  V. From Ohm's law, the current  $I$  in the circuit is given by

$$I = \frac{V}{R} = \frac{3}{10} = 0.3 \text{ A}$$

(b) Since the two resistances are connected in series the current flowing through each is equal to the current  $I$  in the circuit. From Ohm's law, the potential difference  $V_1$  across  $R_1$  ( $= 4 \Omega$ ) is given by  
 $V_1 = I R_1 = 0.3 \times 4 = 1.2 \text{ V}$

(c) The potential difference  $V_2$  across  $R_2$  ( $= 6 \Omega$ ) is given by  
 $V_2 = I R_2 = 0.3 \times 6 = 1.8 \text{ volts}$   
 Notice that  $V_1 + V_2 = V$

**EXAMPLE 9**

Two resistances of  $5 \Omega$  and  $20 \Omega$  are connected to a 6 volt battery as shown in Fig. 8.18. Find (a) the current in the circuit, (b) cur-

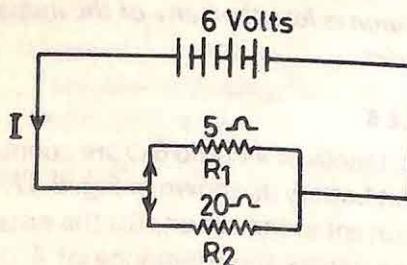


Fig. 8.18

rent in resistance of  $5 \Omega$  and (c) the current in resistance of  $20 \Omega$ .

**Solution**

(a) The total resistance ( $R$ ) in the circuit is given by

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$= \frac{1}{5} + \frac{1}{20} = \frac{4 + 1}{20} = \frac{5}{20} = \frac{1}{4}$$

or  $R = 4 \Omega$

Total potential difference ( $V$ )  $= 6$  volts  
 From Ohm's law the current  $I$  in the circuit is given by

$$I = \frac{V}{R} = \frac{6}{4} = 1.5 \text{ A}$$

(b) Since the resistances are connected in parallel, the potential difference across each is equal to that of the battery ( $V$ )  $= 6 \text{ V}$ .

From Ohm's law, the current  $I_1$  in  $R_1$  ( $= 5 \Omega$ ) is given by

$$I_1 = \frac{V}{R_1} = \frac{6}{5} = 1.2 \text{ A}$$

(c) The current  $I_2$  in  $R_2$  ( $= 20 \Omega$ ) is given by

$$I_2 = \frac{V}{R_2} = \frac{6}{20} = 0.3 \text{ A}$$

Notice that  $I_1 + I_2 = I$

## POINTS TO REMEMBER

1. A moving charge constitutes electric current.
2. Charge flows from a body at a higher electrical potential to a body at a lower electrical potential.
3. The coulomb (C) is the unit of charge. One coulomb is equal to the charge of  $6.24 \times 10^{18}$  electrons.
4. The unit of potential difference is called volt (V). The potential difference between two points is 1 V if 1 joule (J) of work is done to move 1 C of charge from one point to the other.
5. The rate of flow of charge is called current.

$$\text{Current} = \frac{\text{Charge}}{\text{Time}}$$

6. The unit of current is called ampere (A). The current in a conductor is 1 A if 1 C of charge flows through it every second.
7. A cell is a device in which a potential difference is maintained between the terminals by a conversion of chemical energy into electrical energy.
8. Ohm's law states that the ratio of the potential difference between the ends of a conductor and the current flowing through it is constant. This constant is called the resistance of the conductor.

$$R = \frac{V}{I}$$

9. The resistance of a wire depends on its length, thickness and the material of which it is made.
10. The unit of resistance is called ohm ( $\Omega$ ). The resistance of a conductor is 1 ohm if a current of 1 A flows through it when a potential difference of 1 V is maintained between its ends.
11. When resistances  $R_1$ ,  $R_2$  and  $R_3$  are connected in series, the total resistance of the combination is equal to the sum of individual resistances.
12. When resistances  $R_1$ ,  $R_2$  and  $R_3$  are connected in parallel, the resistance  $R$  of the combination is given by the formula

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

## QUESTIONS

1. What do you understand by the term *electrical potential* of a charged body?
2. State the units of charge and current. Define an ampere.
3. State and define the unit of potential difference.
4. (a) Draw a diagram of the simple voltaic cell and label its parts.  
 (b) Draw a labelled diagram showing the inside of a dry cell.  
 (c) Distinguish between primary and secondary cells.
5. (a) State Ohm's law.  
 (b) Describe an experiment to verify the law. Draw a neat circuit diagram and label its parts.  
 (c) State and define the unit of resistance.
6. (a) What is the resistance of a conductor due to?  
 (b) State and define the unit of resistance.
7. The current in a conductor is 0.5 A. How many coulombs of charge pass through the conductor in 1 minute?
8. 0.25 C of charge passes through a conductor in 10 s. Calculate the current in the conductor in milliamperes.
9. A 2 V cell is connected across a small bulb and a current of 0.2 A flows through it. Calculate the resistance of the filament.
10. Calculate the potential difference across a resistance of  $12 \Omega$  if a current of 0.2 A is flowing in it.

- A uniform wire 10m long has a resistance of  $200\ \Omega$ . What is the resistance of the same wire 30 m long? What is the resistance of 5 m of the wire?
- Two resistance  $6\ \Omega$  and  $12\ \Omega$  are connected (a) in series and (b) in parallel. Find the resistance of the combination in each case.
- What resistance must be joined with a  $24\ \Omega$  resistance in order to make a combined resistance of  $8\ \Omega$ ? How must the resistances be joined?
- Calculate the effective resistance between points A and B in the three cases shown in Fig. 8.19.

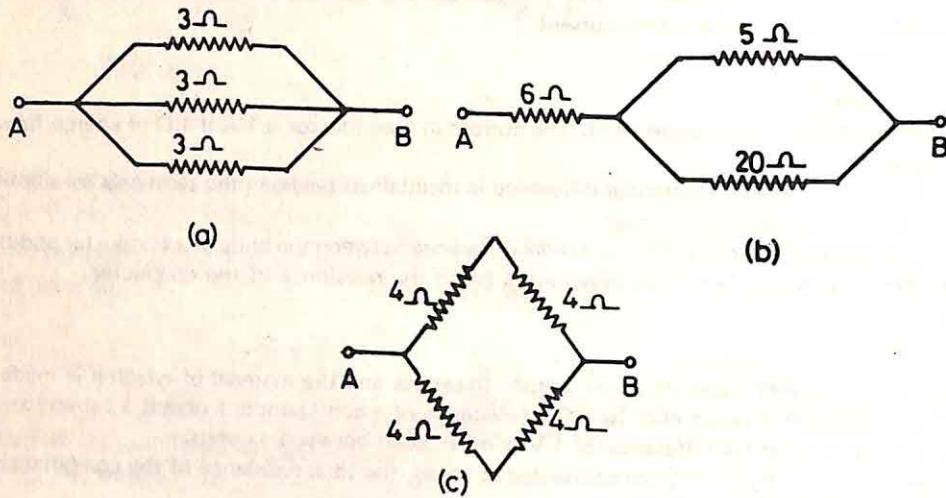


Fig. 8.19

- What will be the readings of ammeter A and voltmeter V in the circuit shown in Fig. 8.20?
- What will be the readings of ammeters  $A_1$ ,  $A_2$  and  $A_3$  in the circuit shown in Fig. 8.21?

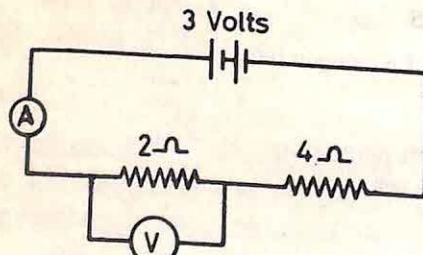


Fig. 8.20

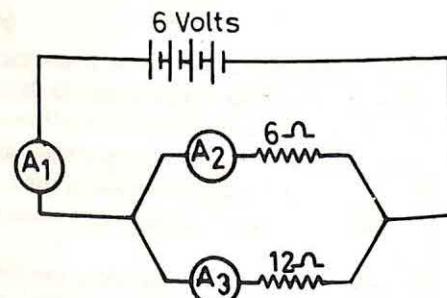


Fig. 8.21

- Mark true or false
  - The longer the wire, the greater its resistance.
  - The thicker the wire, the greater its resistance.
  - Insulators have very low resistance.
  - If two resistances are connected in series, the resistance of the combination is greater than either resistance.
  - If two resistances are connected in parallel, the resistance of the combination is greater than either resistance.

(vi) The voltmeter is connected in series and the ammeter, in parallel in a circuit.  
 (vii) Charge cannot flow between two positively charged bodies.

18. Fill in the blanks using the choices given in brackets.

(i) The unit of charge is \_\_\_\_\_, that of current is \_\_\_\_\_ and of resistance is \_\_\_\_\_ (volt, ampere, coulomb, ohm)

(ii) If a wire is stretched to twice its original length, its resistance will \_\_\_\_\_ (increase, decrease, remain unchanged).

(iii) microcoulomb = \_\_\_\_\_ coulomb ( $10^3$ ,  $10^{-3}$ ,  $10^{-6}$ ,  $10^6$ ).

(iv) \_\_\_\_\_ milliampere =  $10^{-3}$  A (1,  $10^{-3}$ ,  $10^3$ ,  $10^{-6}$ ).

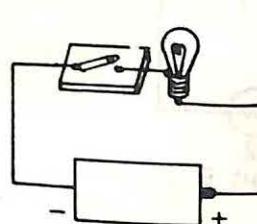
(v) Charge = current  $\times$  \_\_\_\_\_ (voltage, resistance, time)

(vi) The direction of conventional current is opposite to the direction in which \_\_\_\_\_ move (electrons, protons, neutrons).

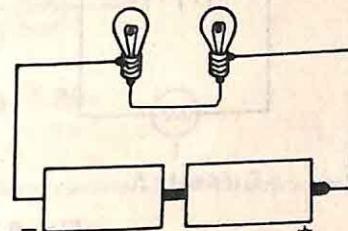
(vii) In a cell, \_\_\_\_\_ energy is converted into \_\_\_\_\_ energy (mechanical, electrical, chemical, gravitational).

(viii) Resistance = potential difference  $\div$  \_\_\_\_\_ (charge, current, power).

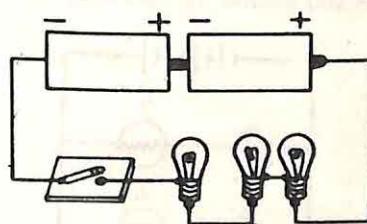
19. Draw a circuit diagram for each of the circuits shown in Fig. 8.22.



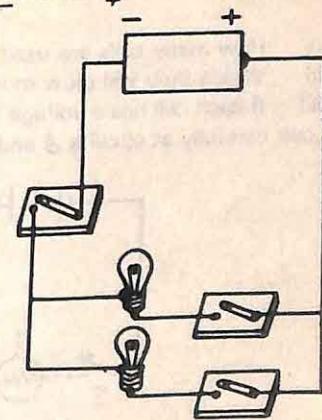
(a)



(b)



(c)



(d)

Fig. 8.22

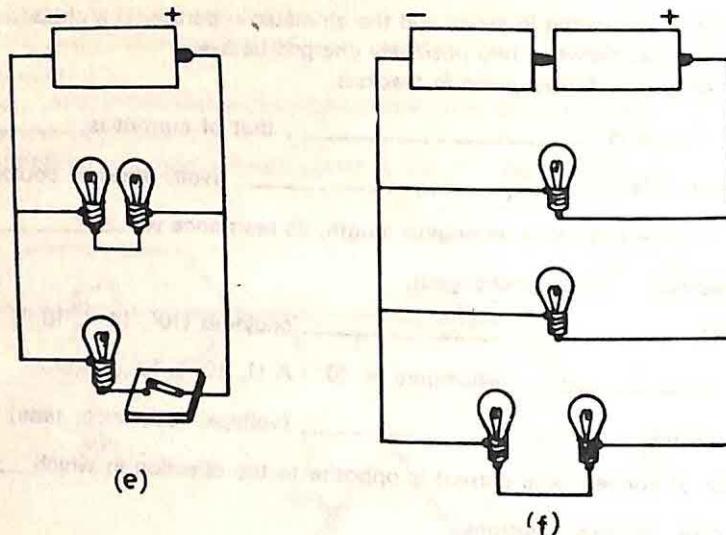


Fig. 8.22

20. The circuits *A* and *B* in Fig. 8.23 use identical bulbs. Look at these circuits and answer the following questions:

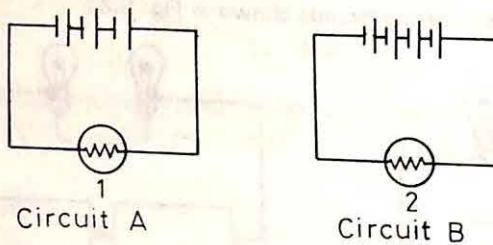


Fig. 8.23

- (i) How many cells are used in circuits *A* and *B*?
- (ii) Which bulb will glow more brightly and why?
- (iii) If each cell has a voltage of 1.5 V, what is the combined voltage of the battery in circuits *A* and *B*?

21. Look carefully at circuits *A* and *B* shown in Fig. 8.24 and answer the following questions.

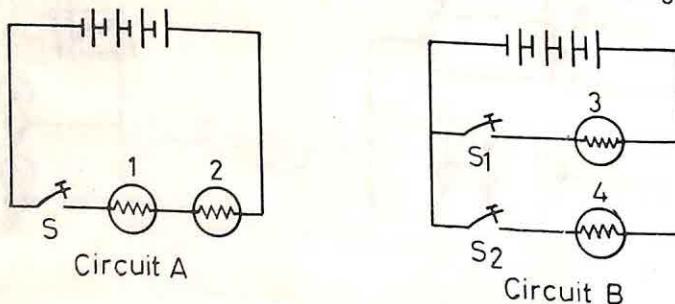
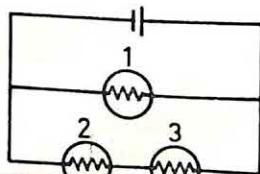
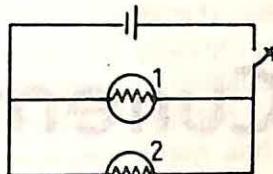


Fig. 8.24

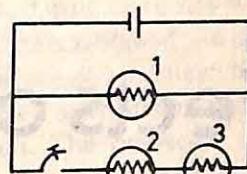
(i) Which is a series circuit?  
 (ii) Which is a parallel circuit?  
 (iii) In circuit, A, the switch S is closed. If the bulb 1 gets fused, will the bulb 2 burn? Give reasons for your answer.  
 (iv) In circuit, B, how can you make only the bulb 3 glow?  
 22. Look carefully at the circuits shown in Fig. 8.25 and tell which bulbs will burn in each case.



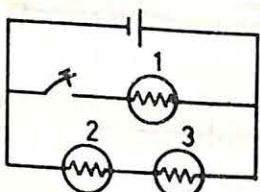
(a)



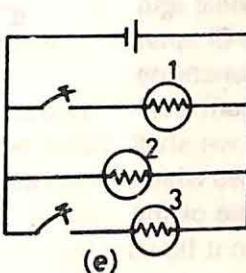
(b)



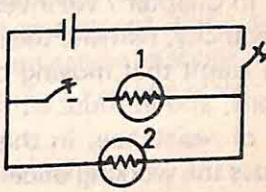
(c)



(d)



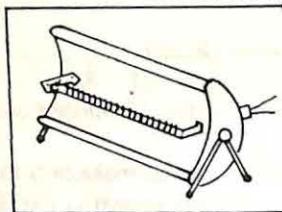
(e)



(f)

Fig. 8.25

23. Draw a circuit diagram showing a battery of four cells connected with three bulbs, each of which is controlled by a separate switch.



# Effects of Current

Electricity plays a very important role in our lives. In Chapter 7 we investigated the origin of electricity, namely, the charge. In Chapter 8 we learnt that moving charges constitute current, and introduced the important concept of resistance. In this chapter we shall discuss the working of certain devices which depend, for their operation, on some of the effects produced by a current when it flows through a conductor. The devices that we shall discuss are electrical appliances we use in our homes such as the electric bulb, electric iron, electric bell, etc. We shall also learn how these devices are connected in a household circuit.

When a current flows through a conductor, it can have three effects—heating effect, magnetic effect and chemical effect.

## Heating Effect of Current

The most obvious effect of current is the heating effect. You know that when a current flows through a bulb, it begins to glow. You can feel the heat if you hold your hand near a lighted electric bulb. Perform the following activity and find out.

### Activity 1

Take about 50 cm of copper wire and wind it on a pencil as shown in Fig. 9.1. Connect

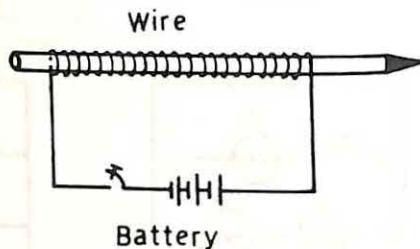


Fig. 9.1

the two ends of the wire to a battery of two or three cells through a switch. Close the switch. After two minutes, touch the wire. It becomes hot.

This experiment shows that when electricity flows through a conductor, it becomes hot. Let us examine the factors on which the heat produced in a conductor depends. If you touch the wire (in the above experiment) after 5 minutes, it becomes hotter. This shows that the heat produced in a conductor depends upon the time for which the electricity is passed through it.

Repeat the same experiment using one cell instead of two or three. You will find that the wire does not become so hot now. This shows that the heat produced in a conductor depends upon the current passing through it.

If you repeat the experiment shown in Fig. 9.1 using a nichrome wire (nichrome is an

alloy of nickel and chromium) instead of a copper wire of the same length and thickness, and allow the same amount of electricity to flow through it for the same time, you will find that the nichrome wire becomes much hotter than the copper wire. This shows that the heat produced in a wire depends on the material of which the wire is made.

Finally if you repeat the experiment shown in Fig. 9.1 using a very short and very thin copper wire, you will find that it becomes so hot that it might begin to glow. Thus, we conclude that the heat produced in a wire depends upon

1. the length and thickness of the wire
2. the current flowing through it
3. the time for which the current flows
4. the material of the conductor

The heating effect of current has many applications. The working of the electric bulb, electric iron and electric heater depends upon the heating effect of current.

### Electric Bulb

An electric bulb consists of a filament which is a wire of pure tungsten. The filament is supported on wires as shown in Fig. 9.2. The

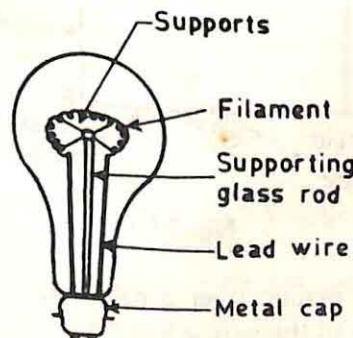


Fig. 9.2

When a current is passed through the filament, it becomes very hot and begins to glow, emitting light.

The filament is extremely thin and has a very high resistance. A tungsten filament is used because tungsten has a very high melting point (about  $3000^{\circ}\text{C}$ ). But at such high temperatures, it quickly reacts with oxygen of the air and gets oxidised. To prevent its oxidation, the air is removed from the bulb and the bulb is filled with inert gases like argon and nitrogen. The presence of inert gases prevents the vaporisation of tungsten.

### Electric Iron

The essential parts of an electric iron are the base plate, a heating element, the pressure plate and an insulated handle as shown in Fig. 9.3. The base plate is a heavy metallic plate

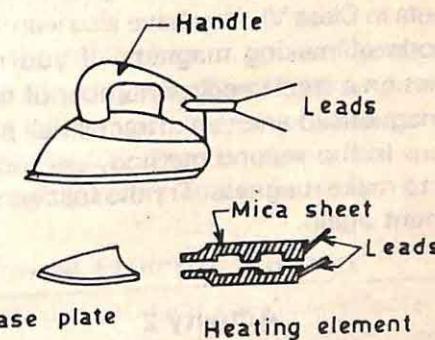


Fig. 9.3

of uniform thickness. The heating element is a nichrome ribbon wound on a mica sheet. The element is placed between the base plate and the pressure plate. When a current is passed through the element, it becomes red hot. Consequently, the base plate also becomes hot. The mica sheet insulates the heating element from the base plate. The outer surface of the iron is polished to reduce heat losses.

ends of the filament are attached to leads of thick wire and is enclosed in a glass bulb.

### Electric Heater

Figure 9.4 shows an electric heater or radiator

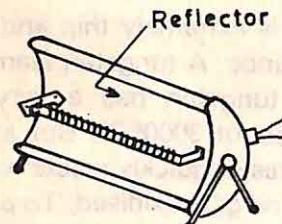


Fig. 9.4

with a reflector. The heating element is a nichrome wire wound on the grooves of a long cylinder of fire clay and fixed at the focus of a polished reflector. The reflector reflects the heat in the desired direction.

### Magnetic Effect of Current

You have learnt about the properties of magnets in Class VI. You have also learnt two methods of making magnets. If you rub a magnet on a steel needle a number of times, it is magnetised and can attract small pieces of iron. In the second method, electricity is used to make magnets. Try the following experiment again.

#### Activity 2

You will need an iron nail about 6-8 cm long, a long piece of plastic-covered (insulated) wire, a cell and a switch. Remove the plastic covering from about 2 cm at each end of the wire. Wind the wire tightly round the nail and connect its ends to a cell through a switch as shown in Fig. 9.5. Close the switch and take a few common pins near the nail. What do you observe? The nail attracts the pins. The nail is magnetised. Now open the switch. The pins fall off. This means that when electricity stops flowing in the coil, the nail loses magnetism.

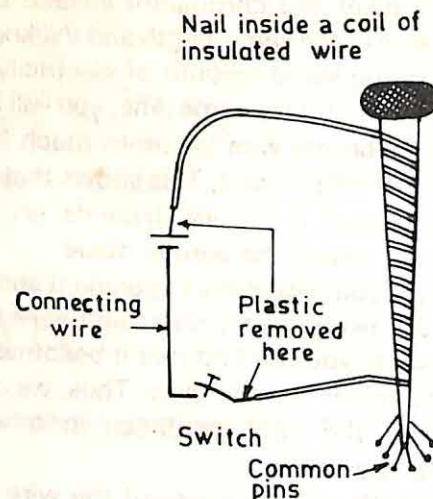


Fig. 9.5

An object of iron magnetised using electricity is called an *electromagnet*. This experiment shows the magnetic effect of current. Here is another experiment which shows that when current flows through a wire, it produces a magnetic effect around it.

Figure 9.6 shows a straight long copper

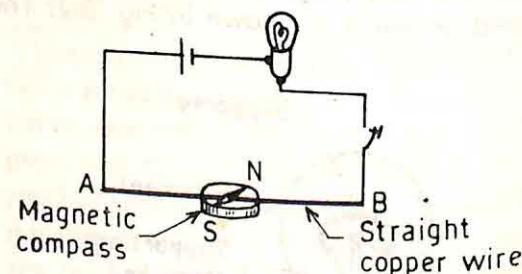


Fig. 9.6

wire AB placed over a magnetic compass. The ends of the wire are connected to a bulb, a switch and a cell as shown. When the switch is open, the magnetic needle points along the north-south direction. When the switch is closed, the magnetic needle deflects to one side. When the switch is opened, it

returns to its original north-south direction. This experiment shows that when electricity flows through wire *AB* (this is indicated by the glowing of the bulb) it produces a magnetic effect around it.

The magnetic effect of current has many applications. Electromagnets are used in electric bells and electric motors. Huge electromagnets are used in cranes to lift heavy objects made of iron. Figure 9.7 shows a

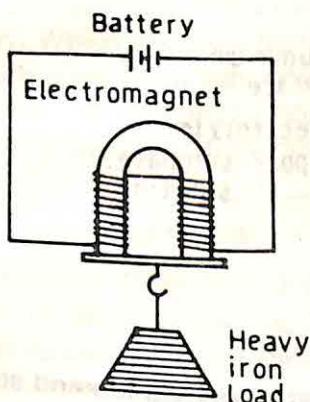


Fig. 9.7

horseshoe type of an electromagnet being used to lift a heavy load of iron.

#### Electric Bell

The working of an electric bell is based on the magnetic effect of current. A horseshoe electromagnet is used in a bell. The various parts of a bell are shown in Fig. 9.8. When the switch is closed, electricity flows through the coil and the horseshoe-shaped iron piece inside the coil is magnetised. Therefore, it attracts the armature. When this happens, a hammer attached to the armature bangs against the gong and a ring is heard. The moment the armature is attracted, the circuit is broken at the adjustable screw. Therefore, the iron piece inside the coil loses magnetism and can no longer attract the armature which falls

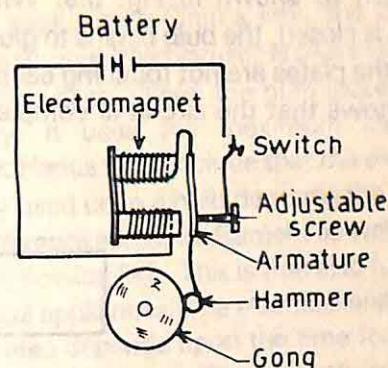


Fig. 9.8

back. The moment the armature falls back, the circuit is completed again. The iron piece inside the coil again becomes a magnet and attracts the armature whose hammer again bangs against the gong. This process of make and break of the circuit goes on and the bell keeps ringing.

In the next chapter you will learn more about the magnetic effect of a current. This effect will be used in the construction of an electric motor. Electric motors are used in fans, refrigerators and in industry.

#### Chemical Effect of Current

Current can produce chemical effects. You know that metals are good conductors of electricity. Some solutions are also good conductors of electricity. For example, electricity can flow through a solution of copper sulphate or silver nitrate or acidulated water. Such solutions are called *electrolytes*. When a current is passed through an electrolyte, a chemical reaction takes place. Your teacher will show you an experiment to see the chemical effect of electricity.

Two aluminium plates are dipped in a solution of copper sulphate in a beaker. The plates are connected to a cell through a bulb and

a switch as shown in Fig. 9.9. When the switch is closed, the bulb begins to glow even when the plates are not touching each other. This shows that the circuit is completed by

## Electrical Energy and Power

You have seen various appliances which work with the electricity such as an electric bulb,

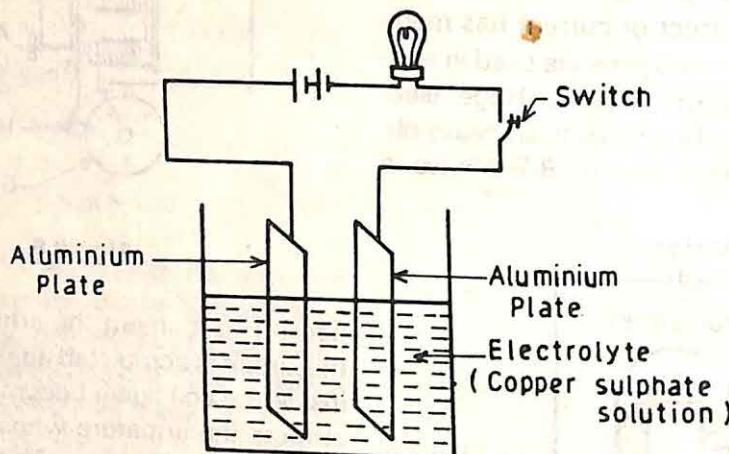


Fig. 9.9

the copper sulphate solution. This means that copper sulphate solution is a conductor of electricity.

The circuit is kept closed for about 15 minutes and then the plates are taken out. What do we find? We observe that one of the plates is coated with a fine reddish covering of copper on it. This method of coating one metal with another is called *electroplating*.

The coating of copper on aluminium plate comes from the copper sulphate solution. This shows that electricity flowing through copper sulphate solution has produced a chemical reaction.

Electroplating has many applications. Electroplating is used to coat utensils with silver or nickel to make them shine. The shiny spoons you use are made of brass and coated with nickel. Iron sheets and pipes are coated with zinc to protect them from rusting. Jewellery made of cheaper metals is electroplated with gold.

electric heater, electric fan and so on. In all these appliances electrical energy is converted into another form of energy. An electric bulb converts electrical energy mostly into light energy. An electric heater converts electrical energy mostly into heat energy. In an electric fan, electrical energy is converted into mechanical energy.

All these appliances use electrical energy. The rate at which electrical energy is used by an appliance is called its *electrical power* or *wattage*. Power is measured in a unit called *watt*, its symbol is *W*. If an appliance uses 1 joule of energy in 1 second, its power is said to be 1 watt. Thus

$$\text{Electrical power} = \frac{\text{Electrical energy used}}{\text{Time taken}}$$

$$1 \text{ W} = \frac{1 \text{ J}}{1 \text{ s}} = 1 \text{ J per s}$$

Power in watts = Energy in joules  $\div$  time in seconds

For convenience, bigger units of power are used.

These are

$$1 \text{ kilowatt} = 1000 \text{ watts}$$

$$\text{or } 1 \text{ kW} = 1000 \text{ W}$$

and 1 mega watt = 1000 kilowatts = 1,000,000 watts

or  $1 \text{ mW} = 1000 \text{ kW} = 1,000,000 \text{ W}$

You must have seen bulbs marked 25 W and 100 W. Which one gives more light? The 100 W bulb gives more light because it has higher power and uses more electrical energy every second than the 25 W bulb.

### Activity 3

Take a torch cell, three fresh dry cells and a few pieces of connecting wires. Connect the bulb to three cells joined in series as shown in Fig. 9.10. Press the switch. The bulb burns

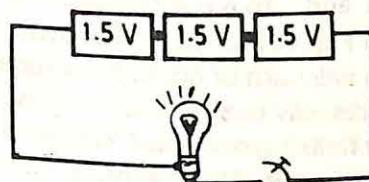


Fig. 9.10

brightly. Next, remove one cell so that there are only two cells in the circuit. Now the bulb burns less brightly. Finally burn the bulb using only one cell. The bulb becomes very dim now. Can you explain your observations?

Each cell has a voltage of 1.5 volts. In the first case, the potential difference across the filament of the bulb is  $1.5 + 1.5 + 1.5 = 4.5 \text{ V}$ , in the second case it is  $1.5 + 1.5 = 3 \text{ V}$  and in the third case it is only  $1.5 \text{ V}$ . The bulb gives out maximum light in the first case because the potential difference is maximum

in this case. From Ohm's law, the current flowing through the filament is also maximum in the first case. When the bulb glows most brightly, it uses the maximum electrical energy. Hence we conclude that the electrical energy used up in a bulb depends the *potential difference* across its filament as well as the *current* flowing in it. This is true also for other electrical appliances. The electrical energy used up also depends upon the time for which the appliance is used. Thus the rate at which an appliance uses electrical energy (i.e. its power) depends on potential difference as well as current.

In fact, the power of an appliance is given by the product of potential difference and current.

$$\text{Power} = \text{Potential difference (or voltage)} \times \text{current.}$$

If the potential difference is expressed in volts and current in amperes, the power is obtained in watts.

Thus

$$\text{Power (in W)} = \text{Potential difference (in V)} \times \text{current (in A)}$$

The powers of some common appliances are given below:

Appliance	Power
Torch bulb	1 W
Electric bulbs	15 W to 200 W
Electric fans	25 W to 60 W
Electric irons	500 W to 700 W
Electric heaters	1000 W to 2000 W

The electrical energy used in our homes, offices and factories is measured by the *electric meter*. You can see this meter on the main switch board of your house. The Electric Supply Undertaking uses a unit called *kilowatt hour* (kWh) to determine the electrical energy consumed.

$$1 \text{ kWh} = 1000 \text{ watt hours}$$

1 watt hour is the energy consumed by an appliance of power 1 W in 1 hour.

Thus

Electrical energy = Electrical power  $\times$  time

$$1 \text{ Wh} = 1 \text{ W} \times 1 \text{ h}$$

$$1 \text{ kWh} = 1000 \text{ Wh}$$

Energy in watt hours = Power in watts  $\times$  time in hours

Note: Watt and kilowatt are units of electrical power and watt hour and kilowatt hour are units of electrical energy.

### EXAMPLE 1

Calculate the power of a fan which works on 240 volts and draws a current of 0.25 A

*Solution*

Potential differences (or voltage) = 240 V

$$\text{current} = 0.25 \text{ A} = \frac{1}{4} \text{ A}$$

$$\text{Power} = \text{voltage} \times \text{current}$$

$$= 240 \times \frac{1}{4} = 60 \text{ W}$$

### EXAMPLE 2

A 100 W bulb is operating on 200 V. Calculate

(a) the current flowing in its filament and  
(b) the resistance of the filament.

*Solution*

$$\text{Voltage} = 200 \text{ V}$$

$$\text{Power} = 100 \text{ W}$$

(a) Now power = voltage  $\times$  current

$$\text{Current} = \frac{\text{power}}{\text{voltage}} = \frac{100}{200} = 0.5 \text{ A}$$

(b) From Ohms law

$$\text{potential difference}$$

Resistance =  $\frac{\text{Current}}{\text{Current}}$

$$= \frac{200}{0.5} = 400 \text{ ohms}$$

### EXAMPLE 3

An electric heater has a power of 2000 W.

(a) How much energy in kilowatt hours does it consume if it is used for 10 hours?

(b) Find the cost of using it for 10 hours at

50 paise per unit of electrical energy.

*Solution*

(a) A 2000 W heater will consume 2000 watt hours of energy in one hour. In 10 hours it will consume 20,000 watt hours = 20 kWh of energy.

(b) 1 kilowatt hour of energy costs 50 paise. Therefore, 20 kWh will cost  $20 \times 50 = 1000$  paise = Rs. 10.

## Electrical Circuits in Our Homes

What type of circuits are used in our houses?

How are various appliances such as electric fans, electric bulbs, electric heaters, etc. connected in a circuit? Perform the following simple experiments and find out for yourself.

### Activity 4

You will need a cell, two torch bulbs, a switch and connecting wires. Connect the two bulbs marked 1 and 2 to a cell through a switch as shown in Fig. 9.11a. Close the switch. Both the bulbs will burn or glow. Now remove one of the bulbs, say bulb 2, and close the switch. Does the bulb 1 glow now? You will find that it does not glow. The reason is that the circuit is broken when the bulb 2 is removed. Therefore, electricity cannot flow through the circuit. Now look at Fig. 9.11b. Suppose bulb 2 is fused; its filament is broken. Do you think bulb 1 will burn if the switch is closed?

The bulbs connected as shown in Fig. 9.11 are said to be connected in *series*. If one of the bulbs is removed or is fused, the other bulb will not burn when the switch is closed. It is clear that the electric bulbs at home or in the classroom are not connected in series. If one of them is fused, the other bulbs still keep burning. Perform the following experiment to find out how bulbs are connected in

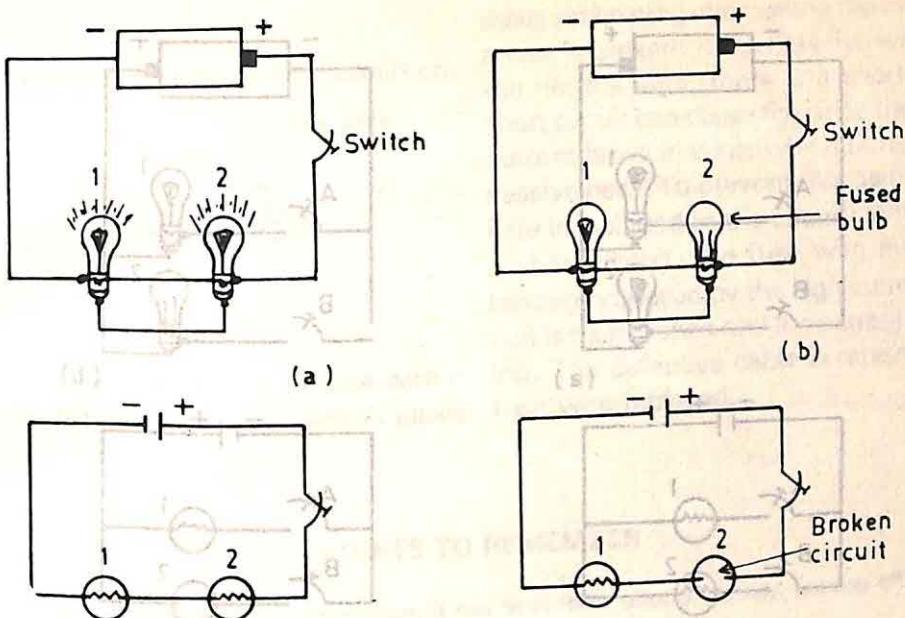


Fig. 9.11

a circuit at home in the class room or in offices.

#### Activity 5

Connect the two bulbs marked 1 and 2 through switches *A* and *B* to a cell as shown in Fig. 9.12(a). Close both switches *A* and *B*. Both the bulbs will burn. Close only switch *A* and leave switch *B* open. You will notice that the bulb 1 burns but the bulb 2 does not. Follow the path of electricity and find out why this happens. Now close switch *B* and leave switch *A* open. The bulb 2 will burn but bulb 1 will not. Can you tell why this happens?

Suppose one of the bulbs, say bulb 2, is fused as shown in Fig. 9.12(b). Close both switches *A* and *B* you will notice that bulb 1 will still burn.

The bulbs connected as shown in Fig. 9.12 are said to be connected in *parallel*. When switch *A* is open and switch *B* is closed, elec-

tricity can flow through bulb 2 because the circuit through bulb 2 is complete. If switch *B* is open and switch *A* is closed, electricity can pass through bulb 1 because it has a complete path through this bulb.

This type of parallel circuit is used in our homes, schools and offices. The electricity we use in our homes is generated at a power station. In a thermal power station, the heat energy of fuels such as coal is converted into electrical energy by a generator. In a hydroelectric power station, the mechanical energy of falling water in a dam is converted into electrical energy. In a nuclear power station, the nuclear energy is converted into electrical energy. The electricity so produced is sent through cables to different cities and villages. The electricity is supplied to our homes and offices at 220 V through underground cables. The ends of the cables are connected to two terminals of the main switch box where the electricity has to be

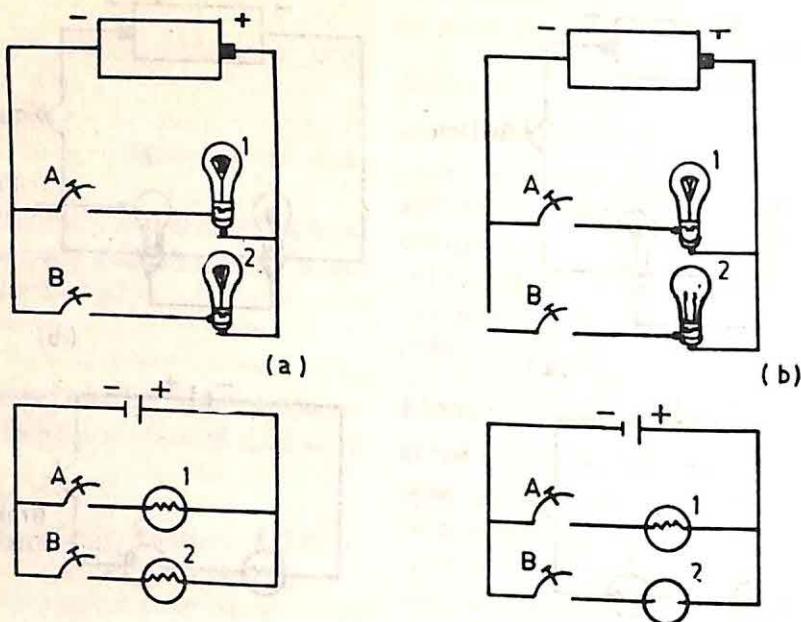


Fig. 9.12

distributed to all parts of the house such as rooms, kitchen, toilet, etc.

The electrical wiring of a house is such that all the circuits are connected in parallel. Figure 9.13 shows how a fan and two bulbs must be connected in a room.

The cable used in a house circuit has three cores of different colours. The *red* wire is the *live* wire, the *black* is the *neutral* wire and the

*green* is the *earth* wire. The metallic body of an electric appliance is connected to the earth. The earthing protects us from electric shock when the appliance is touched. Sometimes, due to faulty wires, the insulation breaks and the live wire comes into contact with the body of the appliance. If the appliance is earthed, the charge will quickly flow to the earth, thus protecting us from electric shock.

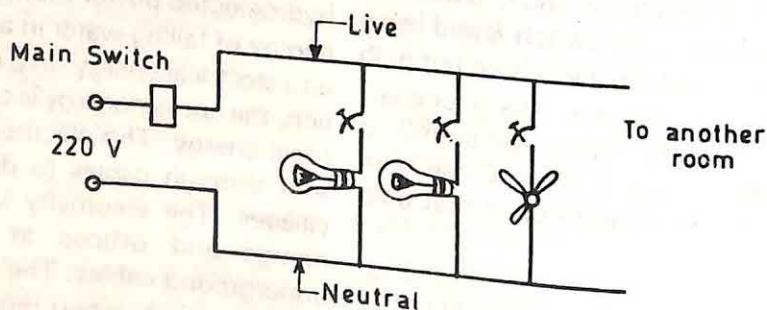


Fig. 9.13

### Electric Fuse

Figure 9.14 shows an electric fuse commonly used in household circuits.

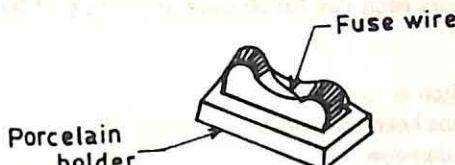


Fig. 9.14

A fuse wire is a short and thin piece of wire which easily

melts on heating. Sometime the insulation of a wire is broken. If the bare live wire touches the neutral wire, there is a short circuit. A short circuit can cause fire since the maximum current flows in wires which burn due to excessive heat. To prevent this damage, a fuse wire is included in the circuit. When there is a short circuit, the fuse wire melts due to heating produced by the high current. The circuit is then broken and the current stops flowing. The defective cable is repaired and the fuse wire replaced.

### POINTS TO REMEMBER

- When a current flows through a conductor, it can have three effects, namely, heating effect, magnetic effect and chemical effect.
- The heat produced in a conductor when a current is passed through it depends upon the resistance of the conductor, the current flowing through it, and the time for which the current flows.
- The heating effect of current is used in the working of an electric bulb, electric iron and electric heater.
- The magnetic effect of current is used in the making of electromagnets and electric motors.
- The chemical effect of current is used in electroplating.
- The power of an electrical appliance is the rate at which it consumes electrical energy.
- The unit of power is the watt. If an appliance consumes 1 joule of energy in 1 second, its power is 1 watt.
- Power (in watts) = voltage (in V)  $\times$  current (in A).
- The electric meter in our homes measures the electrical energy consumed in terms of kilowatt hours. An appliance of power 1 kilowatt will consume 1 kilowatt hour of energy in 1 hour.
- The various electrical appliances we use in our homes are connected in parallel.

### QUESTIONS

- (a) Describe an experiment to show the heating effect of current.  
(b) State the factors on which the heat produced in a wire due to the flow of current depends.  
(c) Name three appliances in which the heating effect is used.
- (a) Describe an experiment to show the magnetic effect of a current.  
(b) Name two devices in which the magnetic effect is used.
- Draw a labelled diagram of an electric bell and explain how it works.
- (a) Describe an experiment to show the chemical effect of a current.  
(b) What is electroplating? How is it useful?
- Which effect of current is used in each of the following cases?  
(i) Electric bulb (ii) electric fan (iii) immersion rod (iv) electric bell (v) electroplating (vi) charging of a battery
- (a) What is wattage?  
(b) State and define the unit of electrical power.  
(c) What is kilowatt hour?  
(a) What is the power of an electric motor which works on 220 V and draws a current of 5 A?

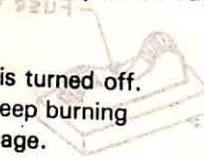
(b) A 60 W bulb is operating on 240 V. Calculate the current flowing in its filament and the resistance of the filament.

(c) An electric iron has a power of 1000 W. How much energy in kilowatt hours will it consume if it is used for 2 hours? Find the cost of using it for 2 hours each day for 30 days at the rate of 50 paise per unit of electrical energy.

8. Explain the following

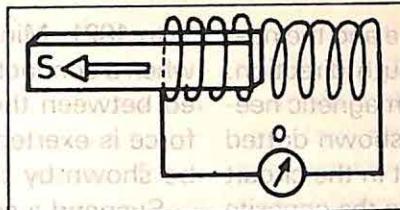
- At home, all lights and fans go off if the main switch is turned off.
- If one bulb is fused, in any one room, the other bulbs keep burning.
- The fuse protects a building or an appliance from damage.
- A torch with four cells gives brighter light than when only two cells are used.

9. Draw a circuit diagram showing a battery of four cells connected with three bulbs, each of which is controlled by a separate switch.



### POINTS TO REMEMBER

### QUESTIONS



# Electromagnetism

Electromagnetism deals with the relationship between electricity and magnetism. Up to the end of the 18th century, scientists believed that there was no relationship between electricity and magnetism. They thought they were different phenomena. But you know that this is not true. You have learnt that a piece of iron can be magnetised by passing a current through a coil of wire wound around it. The piece of iron magnetised by electricity is called an *electromagnet*.

You have also learnt about another magnetic effect of current. This effect was discovered by a Danish scientist, Hans

Oersted in 1820. He discovered that when a current is passed through a wire, it could deflect a magnetic needle kept near it. Oersted's experiment, which shows the relationship between electricity and magnetism, gave birth to a branch of physics called *electromagnetism*.

## Oersted's Experiment: Magnetic Effect of Current

Let us perform the famous experiment that Oersted performed. We need only a magnetic compass needle, a length of wire, a cell and a switch. Set up the circuit as shown in Fig. 10.1. The wire *AB* is set parallel to the

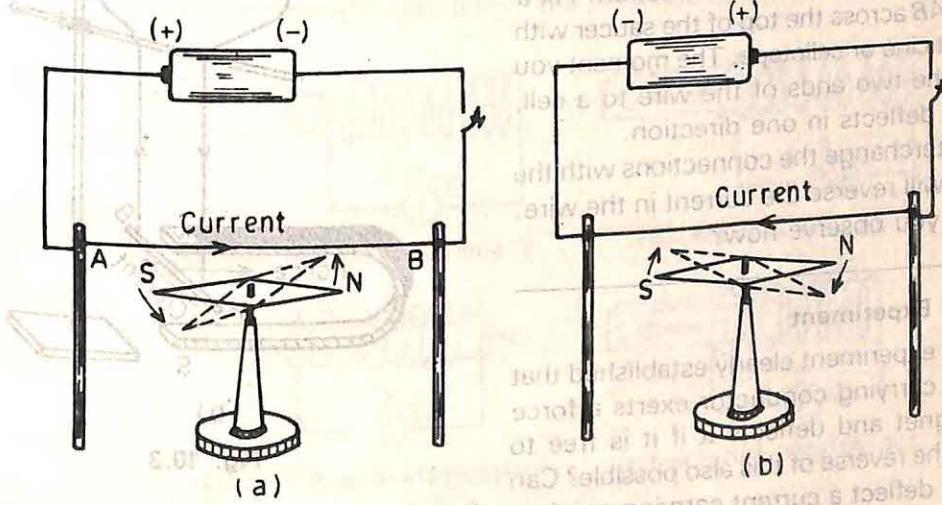


Fig. 10.1

magnetic needle, so that the wire and the needle both point in the north-south direction. When the switch is closed, the magnetic needle swings to a new position, shown dotted in Fig. 10.1a. When the current in the circuit is reversed, the needle deflects in the opposite direction as shown in Fig. 10.1b.

### Activity 1

You can perform Oersted's experiment yourself at home. You will need a used razor blade, a magnet, a saucer, a length of wire and a cell. Break the razor blade into two parts along its length. Stroke a piece of blade with a bar magnet a couple of times. It is magnetised. Float it on water in a saucer (Fig. 10.2). It

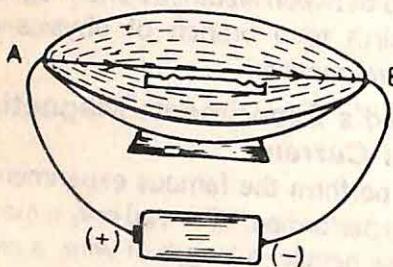


Fig. 10.2

will point in the north-south direction. Fix a thin wire  $AB$  across the top of the saucer with some plasticine or cellophane. The moment you connect the two ends of the wire to a cell, the blade deflects in one direction.

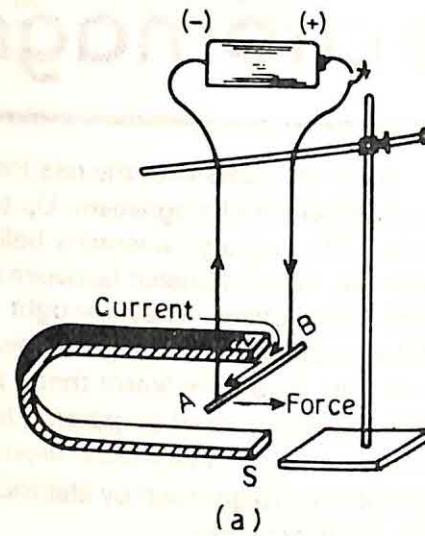
Now interchange the connections with the cell. This will reverse the current in the wire. What do you observe now?

### Faraday's Experiment

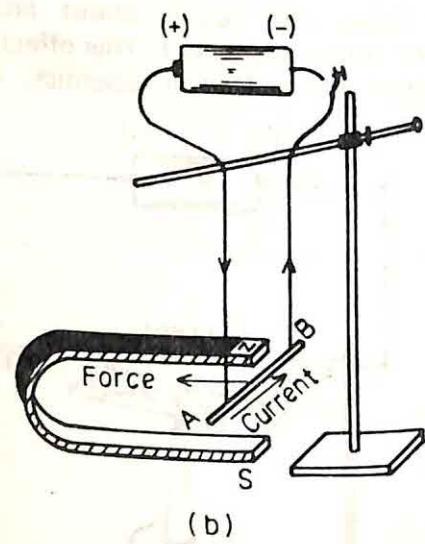
Oersted's experiment clearly established that a current carrying conductor exerts a force on a magnet and deflects it if it is free to move. Is the reverse of this also possible? Can a magnet deflect a current carrying conductor, if it is free to move?

In 1821, Michael Faraday discovered that when a conductor carrying a current was placed between the pole pieces of a magnet, a force is exerted on the conductor. This can be shown by the following experiment.

Suspend a conductor (thick straight wire)  $AB$  between the poles of a horse-shoe magnet by two insulated wires as shown in Fig. 10.3a.



(a)



(b)

Fig. 10.3

Connect the wires to a cell through a switch. Observe what happens when the switch is

closed. You will see that the conductor  $AB$  moves perpendicular to the line joining the N and S poles of the magnet. This indicates that a force acts on a current-carrying conductor placed between the poles of a magnet. Now, reverse the direction of the current. You will notice that the conductor moves in the opposite direction as shown in Fig. 10.3b.

If you do not reverse the current but interchange the north and south poles of the magnet (by flipping the magnet over), the direction of the force of the conductor is again reversed.

Thus we conclude that the direction of the force exerted on a current-carrying conductor placed between the pole pieces of a magnet depends on two factors (i) the direction of the current in the conductor and (ii) the orientation of the magnet with respect to the conductor.

Devices such as galvanometers and electric motors are based on the magnetic effects of current. A galvanometer is a device which is used to detect small currents. An electric motor is a device which changes electrical energy into mechanical energy. The working of these devices is based on the fact that when a current is passed through a con-

ductor placed between the poles of a magnet, it experiences a force.

An ammeter is a galvanometer having a very low resistance and a voltmeter is a galvanometer having a very high resistance. Can you now tell why an ammeter is connected in series and a voltmeter is connected in parallel in a circuit?

Motors are used in homes and in industry. The electric fan has a motor which moves its blades.

### Electromagnetic Induction

So far, you have studied the magnetic effect of a current. Scientists made attempts to observe the reverse effect; they wanted to find out if a magnet could be used to produce an electric current. Joseph Henry (1830) in the USA and Michael Faraday (1831) in the UK independently observed this effect.

Take a coil of insulated copper wire and connect its ends to a galvanometer  $G$  (Fig. 10.4). When a bar magnet is held stationary outside the coil, the galvanometer reading is zero. This is shown in Fig. 10.4a. If the magnet is moved towards the coil, the galvanometer shows a deflection, indicating the presence of current in the circuit. This is

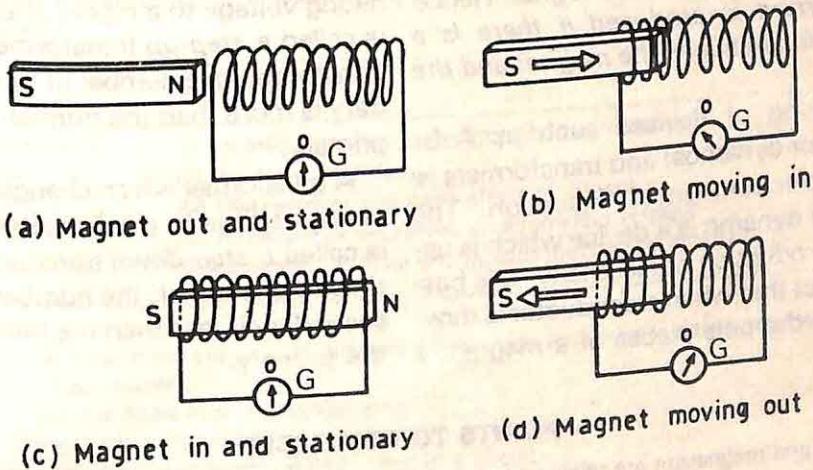


Fig. 10.4

shown in Fig. 10.4b. When the magnet has come to rest inside the coil, the galvanometer deflection again becomes zero as shown in Fig. 10.4c. If the magnet is moved out of the coil, again the galvanometer shows a deflection but in the opposite direction. This is shown in Fig. 10.4d. *A current is produced in the circuit only when the magnet is moving towards or away from the coil.* This current is called *induced current* and this phenomenon is known as *electromagnetic induction*.

This was a very exciting discovery because electricity could now be produced by moving a magnet in or out of a coil. Before this discovery, cells were the only source of electricity. This discovery led to the invention of generators.

If the magnet is continually moved in and out of the coil, an induced current will flow, first in one direction and then in the opposite direction. This type of current which keeps changing direction is called an *alternating current* (or A.C.). Cells give a direct current (or D.C.). A direct current does not change its direction with time.

Induced current is observed also if the magnet is kept stationary and the coil is moved towards or away from the magnet. Hence *induced current is produced if there is a relative motion between the magnet and the coil.*

The working of devices such as A.C. generators (or dynamos) and transformers is based on electromagnetic induction. The generator or dynamo is a device which is used for the production of electricity. It is based on the fact that when a conductor is moved between the pole pieces of a magnet, a

current is induced in the conductor.

A transformer is a device which is used to increase or decrease the magnitude of an alternating voltage. A transformer works on the principle of electromagnetic induction. Take a coil of insulated wire and connect its ends to a source of alternating voltage (or current) as shown in Fig. 10.5. This coil is called

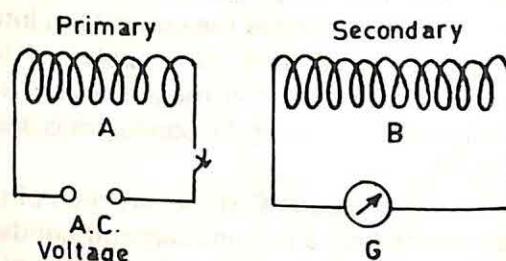


Fig. 10.5

the *primary coil*. Place another coil *B* close to it. The ends of this coil are connected to a galvanometer. This is called the *secondary coil*. When the alternating voltage in the primary coil is switched on, a voltage is induced in the secondary coil. This is indicated by the deflection in the galvanometer. The magnitude of the induced voltage depends on the number of turns in the secondary coil.

A transformer that changes a lower alternating voltage to a higher alternating voltage is called a *step-up* transformer. In a step-up transformer, the number of turns in the secondary is more than the number of turns in the primary.

A transformer which changes a higher alternating voltage to a lower alternating voltage is called a *step-down* transformer. In a step-down transformer, the number of turns in the secondary is less than the number of turns in the primary.

### POINTS TO REMEMBER

- 1 Electricity and magnetism are related to each other.

- If a current is passed through a conductor, it can deflect a magnetic needle placed near the conductor.
- If a current is passed through a conductor placed between the poles of a magnet, the conductor experiences a force and hence it moves. This fact is used in the construction of galvanometers, ammeters, voltmeters and electric motors.
- When there is relative motion between a magnet and a coil of wire, an induced current, and hence an induced voltage is produced in the coil. This is known as electromagnetic induction.
- A generator or dynamo is a device which is used for producing electricity. An A.C. generator is based on the phenomenon of electromagnetic induction.
- The transformer is another device which is based on electromagnetic induction. It is used to increase or decrease an alternating voltage.
- A step-up transformer has more turns in the secondary coil than in the primary coil.
- A step-down transformer has more turns in the primary coil than in the secondary coil.

### QUESTIONS

- You are provided with a cell, a switch, a magnetic needle, a straight wire and some connecting wires. How will you use the apparatus to show the magnetic effect of current?
- Describe an experiment which shows that a force is exerted on a current carrying conductor when it is placed between the poles of a magnet.
- (a) What is a galvanometer?  
(b) State the principle on which it works.
- (a) What is a motor?  
(b) State the principle on which it works.  
(c) Name two devices in your home which work with electric motor.
- (a) What is electromagnetic induction?  
(b) Describe an experiment which demonstrates this phenomenon.
- (a) What is a generator?  
(b) State the principle on which it works.  
(c) Name two devices which use a generator or dynamo.
- (a) What is the function of a transformer?  
(b) State the principle on which it works.  
(c) Distinguish between a step-up and a step-down transformer.  
(d) Can you use a transformer to increase or decrease a D.C. voltage?
- Match the following

Column I	Column II
1. Oersted's experiment	(i) An instrument for detecting small currents
2. Galvanometer	(ii) Produces electricity
3. Motor	(iii) Discovery of magnetic effect of current
4. Generator	(iv) Increases or decreases an alternating voltage
5. Transformer	(v) Converts electrical energy into mechanical energy
9. Mark true or false.	
(i) Electricity and magnetism are entirely different phenomena and there is no relation between them.	
(ii) Cells give a direct current.	
(iii) Alternating current flows in one direction only.	
(iv) A galvanometer shows the existence of current in a circuit.	
(v) A galvanometer shows the direction of current in a circuit.	
(vi) Transformers work only with A.C. voltages.	
(vii) In a motor, mechanical movement is produced by an induced electric current.	

(viii) In a generator, electrical energy is converted into mechanical energy.  
10. Fill in the blanks using the choices given in brackets

(i) An ammeter is a galvanometer having a \_\_\_\_\_ resistance connected in \_\_\_\_\_ with its coil. (high, low, series, parallel).

(ii) A voltmeter is a galvanometer having a \_\_\_\_\_ resistance connected in \_\_\_\_\_ with its coil. (high, low, series, parallel).

(iii) An electric fan uses a \_\_\_\_\_ (generator, transformer, motor).

(iv) A battery eliminator is a \_\_\_\_\_ transformer. (step-up, step-down).

(v) In a step-down transformer, the number of turns in the primary coil is \_\_\_\_\_ than that in the secondary coil. (more, less).

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